UPPER BLACKFOOT MINING COMPLEX

50% Preliminary Restoration Design

Lincoln, Montana

Submitted To:

State of Montana, Department of Justice
Natural Resource Damage Program
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1 Introduction

The Upper Blackfoot Mining Complex (UBMC) is located in Lewis and Clark County, Montana, approximately 15 miles east of Lincoln, Montana at the headwaters of the Blackfoot River (Figure 1-1). Currently, remedial actions related to removal of the Mike Horse Dam and impoundments, and removal of mining tailings associated with the UBMC, are in the final planning stages. This document describes a preliminary restoration plan for the UBMC project area. The purpose of preparing this preliminary design is to define the restoration vision for the site so removal and remediation actions can support a desired restoration outcome. Additionally, during this phase of design development, specific integration issues are identified so remediation and restoration can be done in an efficient and compatible manner in order to maximize benefits to the ecosystem and native fish habitat given the available resources.

To support these purposes, the document is organized into the following sections:

- **Section 1. Introduction** provides an overview of the project history, presents the restoration goals, objectives and restoration strategies, and describes the status of current resources in the project area;
- **Section 2. Design Investigations** describe the studies and investigations that were conducted to support development of the preliminary restoration design;
- **Section 3. Design Criteria** presents design criteria that will be applied to guide channel and floodplain restoration actions;
- **Section 4. Preliminary Restoration Design by Reach** describes the restoration approach and strategies for the project area by reach;
- **Section 5. Integration with Remedial Actions** describes the draft remedial action plan and schedule, and identifies important issues that need to be considered so remediation work supports restoration work and ensures both activities can be accomplished in the most efficient and integrated manner to the greatest extent practical; and
- **Section 6. Conclusion** describes the next steps to move from a preliminary restoration plan to final design and implementation that will result in a restored ecosystem in the UBMC project area.

This report includes the following appendices:

- Appendix A: UBMC Preliminary Design Plan Set;
- Appendix B: Upper Blackfoot River Reach Geomorphic Data Summary Report;
- Appendix C: Hydraulic Modeling Results; and
- Appendix D: Existing Vegetation Communities.

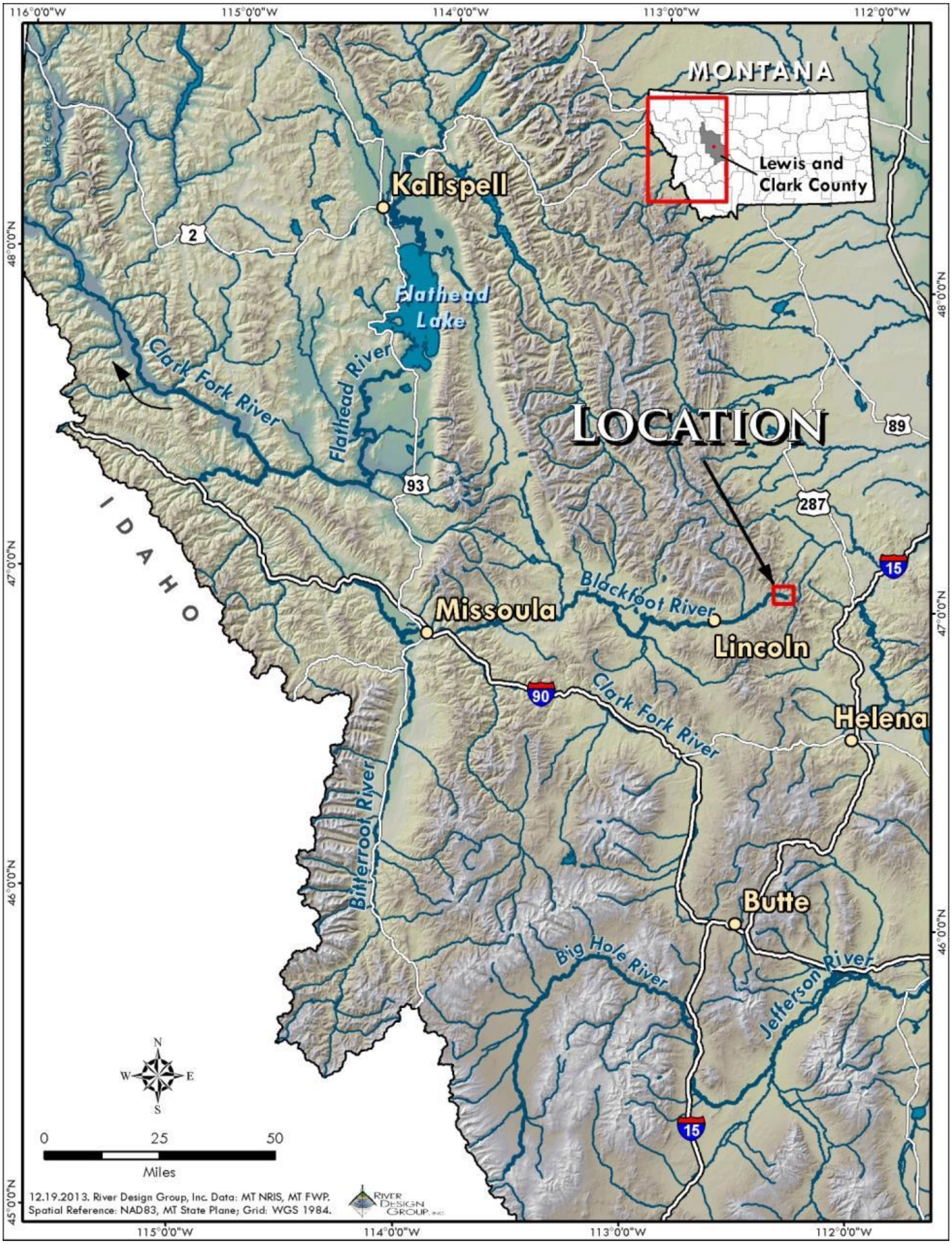


Figure 1-1. Upper Blackfoot Mining Complex project vicinity map.

1.1 Project Background

Numerous reports and studies have been prepared for the UBMC project area that discuss the history of the site as well as the current conditions and proposed remedial and restoration actions. A few of these recent reports are listed below:

- Draft Feasibility Study Report – Upper Blackfoot Mining Complex, CECRA Priority Listed Site (Pioneer Technical Services 2013);
- Upper Blackfoot Mining Complex Conceptual Removal Plan (Spectrum Engineering 2013);
- Conceptual Restoration Plan for the Upper Blackfoot Mining Complex (River Design Group, Inc. et al. 2011);
- Mike Horse Preliminary Design Report Draft (MT DEQ 2010);
- Engineering Evaluation/Cost Analysis for the Mike Horse Dam and Impounded Tailings, Lower Mike Horse Creek, Beartrap Creek and the Upper Blackfoot River Floodplain Removal Areas: Upper Blackfoot Mining Complex, Lewis and Clark County, MT (Hydrometrics 2007);
- Action Memorandum for the Removal Action for the Mike Horse Dam and Impounded Tailings, Lower Mike Horse Creek, Beartrap Creek and the Upper Blackfoot River Floodplain Removal Areas, Upper Blackfoot Mining Complex Site (Helena National Forest 2007); and
- Draft Assessment of Injuries and Damages: Upper Blackfoot Mining Complex, Lewis and Clark County, Montana (Stratus Consulting 2007).

Mining activities began in the UBMC project area in the late 1800s and continued into the 1950s. The 1930s and 1940s were the most active mining periods with mining ceasing in the 1950s; however, exploration activities continued after the 1950s. Lead, zinc, and copper were the major mine products, with some minor production of gold and silver. In 1941, the Mike Horse Dam was constructed across Beartrap Creek creating the Mike Horse Tailings Impoundment where tailings from the Mike Horse Mine mill were disposed. In 1975 the Mike Horse Dam was breached during a spring storm event that produced heavy runoff that combined with rapid spring runoff. The breach released an estimated 100,000 tons of tailings and other materials into the UBMC project area below the dam. The dam was modified and repaired in the fall of 1975 after this breach event (Hydrometrics 2007).

Regulatory activities began in the UBMC in 1987 to reclaim the Mike Horse Mine under Montana's abandoned mine reclamation program (Hydrometrics 2007). To support reclamation activities, several studies evaluated soils, surface water and groundwater in the project area. Water quality impairments were described for the Blackfoot River above Lander's Fork, Mike Horse Creek, and Beartrap Creek within the Blackfoot Headwaters TMDL Planning Area (MT DEQ 2003). Findings of these reports have shown soils, mine waste tailings, and surface waters in the project area pose potential risks to human health and the environment due to metal concentrations. The integrity and safety of the Mike Horse Dam has also been evaluated and was found to have insufficient spillway capacity during flood events (Hydrometrics 2001a as cited in Hydrometrics 2007). Further analysis of the dam found that it could be susceptible to damage or failure in the event of an earthquake (USFS 2005 as cited in Hydrometrics 2007). Due to these findings the United States Forest Service (USFS) recommended that the dam be taken out of service (USFS 2005 as cited in Hydrometrics 2007).

In 2007, Stratus Consulting prepared an assessment of injuries and damages within the Upper Blackfoot River drainage based on existing data. This report found that groundwater in the project area has metal concentrations that exceed Montana's human health standards. It also found that surface water in Mike Horse Creek, Beartrap Creek, and the Upper Blackfoot River have concentrations of zinc and cadmium that exceed acute criteria and are sufficiently high to cause harm to aquatic life. Metal concentrations collected from sediments from Mike Horse Creek and the Upper Blackfoot River were found to be high enough to be likely to cause injury to benthic invertebrates. Macroinvertebrates were found to be absent from some portions of the Upper Blackfoot River, and in other locations only metal tolerant species are present. Mine tailings in the project area form sites that may be devoid of riparian vegetation.

In 2007, Hydrometrics prepared an Engineering Evaluation and Cost Estimate to provide a process and rationale for developing, screening, and evaluating potential response actions designed to address mining-related impacts on portions of the UBMC project area. The objective of the document is to develop, present, and compare removal action alternatives that may be used to reduce or eliminate potential human health and environmental risks posed by mining-related impacts on certain USFS managed lands in the UBMC project area. The comparative analysis of alternatives was based on their relative effectiveness, ability to be implemented, and costs. Based on this document, the USFS prepared an Action Memorandum (2007) that selected and approved the following action alternatives:

- Total removal of Mike Horse Dam and associated impounded tailings;
- Total removal of mine wastes below Mike Horse Dam;
- Removal of concentrated and intermixed mine tailings along the Beartrap Creek channel; and
- Total removal of mine waste material from a portion of the Upper Blackfoot River.

A conceptual removal plan was developed by Montana Department of Environmental Quality (DEQ) in 2010 and 2013. The 2013 draft conceptual removal plan describes the general approach and schedule for remedial actions, and how restoration actions will be integrated in a phased approach concurrent with removal activities. This preliminary design report focuses on the restoration aspect of the project.

1.2 Evaluation of Alternatives

As part of the development of a restoration plan, alternatives are considered in selecting a preferred alternative for the plan. This process began with the conceptual restoration plan completed in 2011 (River Design Group, Inc. et al. 2011) where restoration objectives were identified and opportunities to integrate with DEQ were noted. Given the potential opportunities to integrate restoration with remediation, the State analyzed (1) no action, (2) perform restoration after DEQ remedy is complete, and (3) perform restoration in coordination with remedy.

1.2.1 Description of Alternatives

Alternative 1: No Action. Alternative 1 is the no action alternative. It is a required alternative under the federal NRD assessment regulations, and allows for comparison to other alternatives. The no action alternative will incorporate the remedial actions slated for the UBMC without restoration inputs throughout the approximate 4-year cleanup effort.

Alternative 2: Perform Restoration After DEQ Remedy is Complete. Under Alternative 2, remedial work would be completed for the UBMC, and then restoration work would subsequently be performed as a separate phase. Work would be planned independently and contractors would be hired independently of DEQ's remedial process.

Alternative 3: Perform Restoration in Coordination with DEQ Remedy. Under Alternative 3, restoration work would be planned and implemented concurrently with remedial work. The Natural Resource Damage Program's (NRDP's) and DEQ's design teams would communicate frequently to make sure remedial and restoration designs are compatible, and contracting would be combined where possible so the same contractor is performing remediation and restoration construction and revegetation work.

1.2.2 Evaluation of Alternatives

Under the U.S. Department of Interior (DOI) Natural Resource Damage (NRD) regulations, a Trustee's restoration plan should evaluate a reasonable number of alternatives for restoring, rehabilitating, replacing, or acquiring the equivalent of injured natural resources based on all relevant considerations, including the DOI legal criteria (43 CFR §11.93, §11.81, and §11.82). Below, the three restoration plan alternatives are evaluated using seven evaluation criteria. These include criteria set forth in the DOI's NRD assessment regulations (43 CFR §11.82(d)) which Trustees are to use when selecting the restoration plan alternatives.

The evaluations below provide a summary description of each criterion and how each of the three alternatives meets that criterion. Section 1.2.3 provides an overall summary of these criterion- specific analyses and identifies the State's preferred alternative based on the collective analysis of the ten criteria.

Technical Feasibility

Under this criterion, the State evaluates the degree to which each alternative employs well-known and accepted technologies and the likelihood that the alternative will achieve its objectives. Application of this criterion focuses on an evaluation of the alternatives' relative technological feasibility. Alternative 1 is technically feasible. Alternative 2 is technically feasible in general terms, but would become less technically feasible with increasing sophistication of restoration actions, in particular when significant earthwork is required for restoration such that remediated areas would be re-disturbed. Alternative 3 is technically feasible and has been shown to be successful on somewhat similar large cleanup projects in Montana such as Silver Bow Creek and Milltown Dam.

Relationship of Expected Costs to Expected Benefits

Under this criterion, the State examines whether an alternative's costs are commensurate with the benefits it provides. In doing so, the State will need to determine the costs associated with the alternative, and the benefits that would result from the plan.

For this criterion, Alternative 3, coordination with DEQ, is superior to Alternative 1 (the no action alternative) and Alternative 2 no coordination with DEQ. For Alternative 1, there would be a significant reduction in injuries; however, because of the significant injuries to the natural resources in the UBMC, a lack of benefit beyond what remedy will do would be an unacceptable outcome.

Alternative 2 offers net expected benefits compared to expected costs, by providing fisheries and overall ecosystem improvement. However, benefits would be limited by remedial goals, which could potentially limit opportunities for restoration actions. For example, remediation might construct stream channels and floodplains that meet cleanup objectives but do not set the stage for restoring aquatic habitat and the riparian ecosystem. Alternative 3, coordinating with DEQ, results in the greatest benefits for the least cost as areas would not subjected to construction-related activities twice, once for remediation and another time for restoration.

Cost-Effectiveness

Under this criterion, the State evaluates whether the alternative accomplishes its goal in the least costly way possible. In evaluating this criterion, the State considers whether the alternative is consistent with existing plans related to remediation and restoration, and whether the work can be completed with available funds.

For this criterion, Alternative 3 is superior to Alternative 1 and Alternative 2. Alternative 1 is not cost effective because restoration would not occur. Alternative 2 would be less cost-effective than Alternative 1 and 3 because a lack of coordination between DEQ and NRDP would result in redundancy with respect to both design and implementation phases. Alternative 3 would allow DEQ and NRDP to coordinate remediation and restoration during the design process so one contractor can complete both remedial and restoration construction and revegetation work at the same time. Having one contractor complete both remediation and restoration work will result in cost savings compared to separate contractors completing each component at different times.

Results of Response Actions

Under this criterion, the State considers the results or anticipated results of response actions underway, or anticipated, in the UBMC. Alternatives 1, 2 and 3 do not interfere with planned response actions, but Alternatives 2 and 3 enhance planned response actions.

Adverse Environmental Impacts

Under this criterion, the State weighs whether, and to what degree, the alternative will result in adverse impacts to both the physical and human environment. Specifically, the State will evaluate significant adverse impacts, which could arise from the alternative, short- or long-term, direct or indirect, including those that involve resources that are not the focus of the project.

Temporary impacts are anticipated for Alternatives 1, 2 and 3 due to construction activity. Alternative 3 would have the least adverse environmental impacts because the project area would only be subject to one cycle of construction activity, but the end result would still be a reduction in contamination and improvements to fisheries and the ecosystem.

Recovery Period and Potential for Natural Recovery

Under this criterion, the State evaluates the merits of the alternative in light of whether the resource is able to recover naturally and, if a resource can recover naturally (i.e., without human intervention), how long that will take. (The term “recovery” refers to the time it will take an injured natural resource to recover to its “baseline,” i.e., pre-injury condition.)
As noted in documents listed above, the UBMC is not on a natural recovery trajectory, there is a high risk of continued contamination from annual groundwater fluxes and there is a high risk of catastrophic failure of the Mike Horse Dam impoundment. Alternative 1 would result in an increased recovery period and a decrease in potential for natural recovery because no restoration would be coordinated with remedy. Alternative 2 and Alternative 3 would both improve potential for natural recovery because the remediation and restoration actions combined would result in direct and immediate improvement to aquatic habitat and broad ecosystem conditions. Alternative 3 has the greatest potential to spur recovery because an integrated, coordinated approach will have fewer constraints with respect to restoring ecosystem function (see Relationship of Expected Costs to Expected Benefits above).

Federal, State, and Tribal Policies, Rules, and Laws

Under this criterion, the State considers the degree to which the alternative is consistent with applicable policies of the State of Montana and applicable policies of the federal government and Tribes (to the extent the State is aware of those policies and believes them to be applicable and meritorious). In addition, projects must be implemented in compliance with applicable laws and rules, including the consent decrees. As part of the evaluation of this criterion, the State assesses whether the alternative would potentially interfere, overlap, or partially overlap with the restoration work covered under current or planned consent decrees or restoration plans.

All alternatives are compliant with applicable law. The State would require or obtain all needed permits and authorizations.

1.2.3 Evaluation Summary

The criteria that are most influential in this analyses are cost:benefit, cost effectiveness, and recovery period/potential for natural recovery. Under the no action alternative no restoration benefits would occur. The injury to the UBMC has been documented and there is not potential for the natural system to recover without remediation and restoration actions in a reasonably short time period.

Alternative 2 would provide benefits to aquatic habitat and the ecosystem in general; however the potential for natural recovery of baseline conditions would be limited due to constraints imposed by completing remediation work separately from restoration work. Because remediation would emphasize removing contamination and reducing likelihood of re-contamination from groundwater, a cleanup project driven solely by remedial goals is likely to include hard infrastructure and a separation of water and substrate. Because a functioning floodplain requires connectivity between land and water (floodplain and channel), restoration would potentially need to make significant structural changes to work completed by remediation to achieve restoration goals.

Alternative 3 has the greatest cost:benefit ratio and overall cost-effectiveness because of the efficiencies gained by integrating and coordinating both design and implementation between NRDP and DEQ. This integration model has been proven at both Silver Bow Creek and Milltown Dam in Montana, and these projects were managed by NRDP and DEQ. Alternative 3 also has the greatest natural recovery potential because this alternative offers maximum flexibility for including structural components important to restoration as part of the design, such as connectivity between river and floodplain and other subtle grading that can result in highly functioning wetlands. By coordinating remediation and restoration, there are also opportunities to preserve and tie into existing highly functioning habitats adjacent to where remediation will occur.

Because Alternative 3 is superior for the three criteria summarized above, the State selects Alternative 3 as the Preferred Alternative. For the other four criteria, Alternative 2 and Alternative 3 are similar.

1.3 Project Vision, Goals and Objectives

The vision for the project area is to restore self-sustaining ecological processes that will result in clean, connected habitat for westslope cutthroat trout (*Oncorhynchus clarkii lewisi*), support downstream populations of bull trout (*Salvelinus confluentus*) and other important aquatic species, and maintain adjacent riparian and terrestrial habitat to support wildlife populations that depend on those habitats. Specific project area goals and objectives are described below. Ecological restoration described for this project integrates a range of disciplines regarding river restoration (e.g. empirical, analog, and analytical based methods), and principles outlined by the Society for Ecological Restoration.

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SERI 2004). It is an intentional activity that initiates or accelerates ecosystem recovery with respect to species composition, community structure, ecological function, suitability of the physical environment to support biota and connectivity with the surrounding landscape (Clewell et al. 2007). The restored ecosystem is sufficiently resilient to endure the normal periodic stresses that serve to maintain the integrity of the ecosystem (Naimen et al. 2005). A common goal for the restoration of natural ecosystems is to recover self-renewing processes to the point where assistance or maintenance from restoration practitioners is no longer needed (SERI 2004). At the same time, it is recognized that the cost-effectiveness of any component of plan will be a key consideration given the finite quantity of funds for both remedy and restoration.

Remedy is expected to substantially reduce injuries to the UBMC and provide immediate benefits to the ecosystem. However, remedial actions will not address the full spectrum of ecosystem functions. Ecological restoration, on the other hand, sets the system on a trajectory of self-sustaining ecological processes that support functions like maintaining clean water, and providing both aquatic and terrestrial habitat over the long-term. While the remedial actions focus on removing the source of ecosystem degradation (mainly contamination from mining activities), ecological restoration will focus on creating conditions that can sustain a resilient stream and riparian system where ecological processes are driven by natural disturbances, and the system is able to respond to disturbances in ways that do not result in degraded habitat. Because ecological restoration ultimately relies on natural processes, the time frame to achieve desired future conditions described in this document will vary. For example, some components of aquatic habitat will function soon after restoration actions are implemented; on the other hand, it will take several decades to achieve a multi-layered conifer-dominated riparian area within some portions of the floodplain.

Specific elements of the restoration vision include: channel and floodplain are connected, and a diverse riparian forest is present and contributing nutrients to the aquatic environment, providing roughness to the floodplain surface and reducing flood flow velocities, filtering nutrients and sediments before they reach the aquatic environment, and providing habitat for insects, birds, and other wildlife. The exact differences between remedy and restoration will not be ascertained until remedial designs are completed. It is expected that remedial contractors will often perform both remedy and restoration actions at the site and coordination will be critical. In summary, the intention is for restoration to be planned and implemented in an integrated manner with the remediation actions set forth in the Action Memorandum (Helena National Forest 2007).

Table 1-1 summarizes restoration objectives. As noted, these objectives are common to all reaches with the exception of Reach 1 Upper Mike Horse Creek where the presence of permanent infrastructure will impose several constraints on restoration. In particular, adit drains will remain a perpetual source of acid mine drainage and the infrastructure to remain in place will limit the width of the restored channel and floodplain corridor. In addition, it is likely the inherent steep slopes of the channel and valley historically inhibited fish passage from Upper Beartrap Creek into Mike Horse Creek. For these reasons, providing clean water that supports aquatic life in Reach 1, and minimizing sediment inputs to the channel through road decommissioning/relocation and removal of unnecessary infrastructure, have been identified as the primary restoration objectives for Mike Horse Creek.

Table 1-1. Restoration objectives for UBMC project reaches.

Objectives	**UBMC Project Reach**					
	1	**2**	**3**	**4**	**5**	**6**
Produce clean water consistent with supporting aquatic life and/or westslope cutthroat and bull trout habitat.	✓	✓	✓	✓	✓	✓
Create complex aquatic habitat components such as depth, velocity, substrate, cover, and pools that support populations of westslope cutthroat trout and other aquatic organisms.		✓	✓	✓	✓	✓
Construct a stream channel that is connected to the floodplain and interacts with the floodplain in terms of surface flow and sediment exchange.	✓	✓	✓	✓	✓	✓
Maximize riparian and floodplain habitats and functions.		✓	✓	✓	✓	✓
Minimize sediment inputs to the channel resulting from upland and/or instream source areas.	✓	✓	✓	✓	✓	✓
Improve existing and future proposed stream crossings to provide for fish passage and transport flows, sediment and debris.	✓	✓		✓	✓	
Incorporate, to the greatest extent practical, historical (buried) floodplain and terrace surfaces and associated features including stumps and other roughness elements.		✓	✓	✓	✓	✓
Relocate access roads outside of the channel migration zone and where possible, remove all unnecessary infrastructure.	✓				✓	✓

1.4 Restoration Strategies

Montana Department of Environmental Quality is in the final stages of completing the removal plan for contaminated waste in the UBMC. To ensure ongoing remedial actions support the desired restoration outcome, and do not preclude implementation of a range of potential restoration alternatives, preliminary restoration strategies were developed during the conceptual design phase. Table 1-2 summarizes the preliminary strategies by reach. These strategies were used to develop restoration design criteria presented in Section 3 of this report.

Table 1-2. Restoration strategies for UBMC project reaches.

Strategies	UBMC Project Reach					
	1	**2**	**3**	**4**	**5**	**6**
Design primary channel to convey the effective or bankfull discharge and a connected floodplain to accommodate larger flood events.	✓	✓	✓	✓	✓	✓
Provide for sediment transport continuity and sufficient capacity to transport the available sediment load.	✓	✓	✓	✓	✓	✓
Construct a low sinuosity, highly entrenched, confined stream channel with step-pool morphology developed within a narrow, well-vegetated riparian corridor.	✓					
Construct a low sinuosity, moderately entrenched stream channel with step-pool morphology and interspersed riffles, developed within a well-vegetated riparian corridor.		✓	✓	✓		
Construct a moderately sinuous, moderately entrenched riffle-pool stream channel with a broad, well-vegetated floodplain.					✓	
Construct a moderately entrenched, step-pool channel with interspersed riffles and rapids transitioning to a slightly entrenched, meandering channel with riffle-pool bedforms and a well-developed floodplain.						✓
Create a complex and narrow vegetated floodplain that functions to filter sediment and other chemical inputs from adjacent uplands, legacy mining and reclamation-related infrastructure, and residual metals.	✓					
Develop a narrow riparian area and floodplain that will occupy the full valley bottom width transitioning to an upland conifer forest.		✓	✓	✓		
Create a complex, broad vegetated floodplain with side channel habitats that supports a mosaic of conifers, cottonwoods, aspen and riparian shrubs.					✓	✓
Relocate access roads and other unnecessary infrastructure outside of the channel migration zone and provide for fish passage at existing and future proposed stream crossings.	✓	✓	✓	✓	✓	✓
Minimize remedial actions to avoid disturbance to the existing, high quality fen wetland.						✓

1.5 Project Area Description

The UBMC project area includes the site of Mike Horse Dam, the Mike Horse Tailings Impoundment, the Upper Blackfoot River and primary tributaries including Anaconda Creek, Stevens Gulch, Shaue (Shave) Gulch, Paymaster Creek, and Pass Creek. Figure 1-2 shows an overview of the UBMC project area, including stream reach delineations.

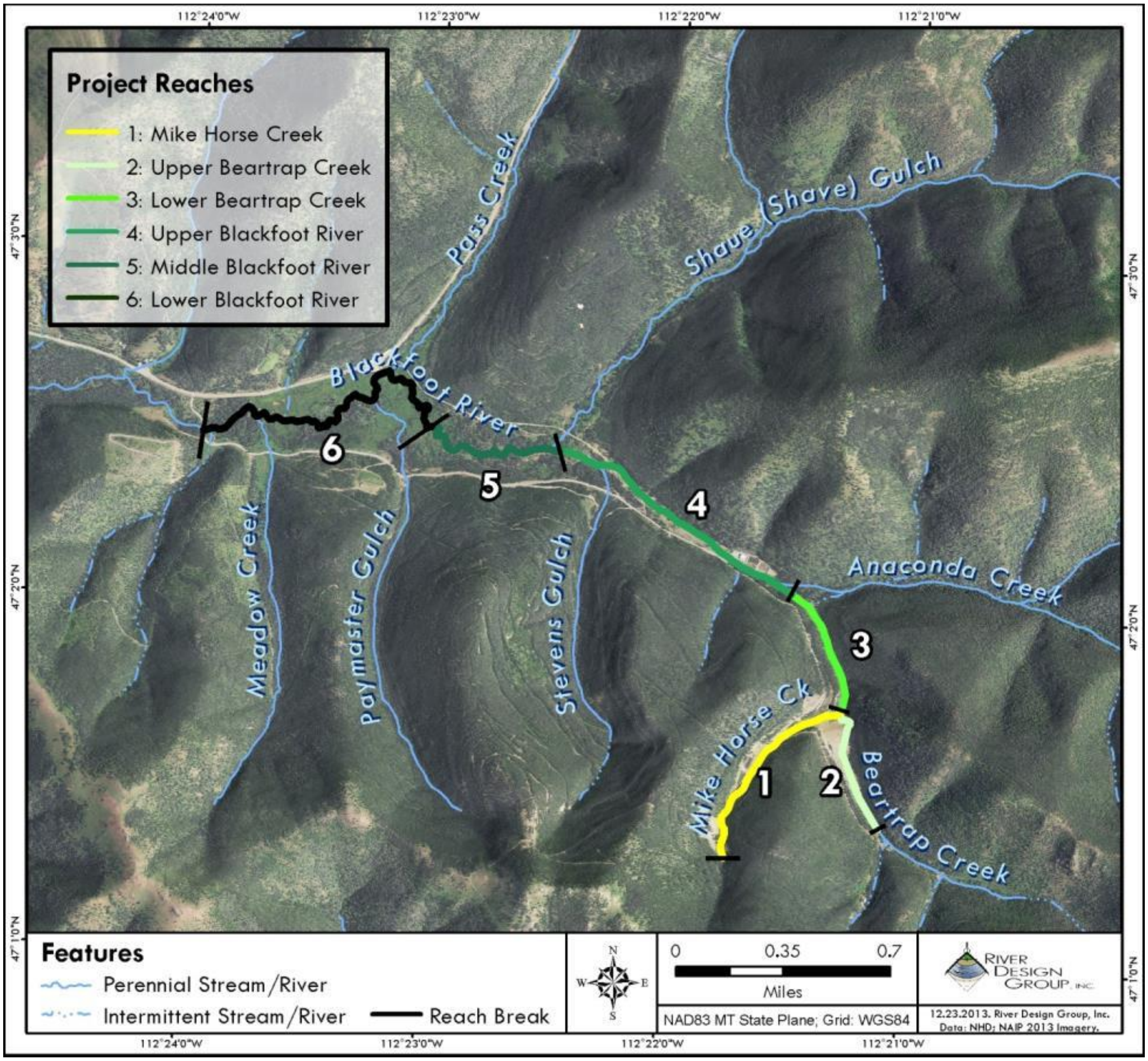


Figure 1-2. UBMC project and reach break overview.

1.5.1 Reach Delineations

The UBMC project area was delineated into stream reaches based on several attributes including valley and stream types, stream order and tributary confluences, major infrastructure, and vegetation characteristics. Stream reach delineations are shown in Figure 1-2 and described generally in the following section.

Reach 1 Mike Horse Creek

Reach 1 Mike Horse Creek is situated in the upper headwaters of the UBMC project area and includes approximately 0.7 miles of channel from the Upper Mike Horse waste piles downstream to the confluence with Beartrap Creek. Significant geographic features in Reach 1 include the Mike Horse Mine, waste repository and associated infrastructure. The draft removal plan estimates removing approximately 90,000 cubic yards (cy) of tailings in Reach 1.

Reach 2 Upper Beartrap Creek

Reach 2 Upper Beartrap Creek includes approximately 0.5 miles of channel from the diversion located at the head of the Mike Horse Tailings Impoundment downstream to the confluence with Reach 1 Mike Horse Creek. The primary geographic feature in Reach 2 includes the Mike Horse Dam and Tailings Impoundment. Constructed in 1941, the earthen embankment was constructed across Beartrap Creek just upstream of the confluence with Reach 1 Mike Horse Creek to serve as an impoundment for tailings from the Mike Horse Mine flotation mill (Tetra Tech 2008). Reach 2 encompasses approximately 18 acres of potential riparian and floodplain area that is presently impacted by the tailings impoundment. The draft removal plan estimates removing approximately 400,000 cubic yards of tailings in Reach 2, including the tailings impoundment.

Reach 3 Lower Beartrap Creek

Lower Beartrap Creek forms at the confluence of Reach 1 Mike Horse Creek and Reach 2 Upper Beartrap Creek and extends 0.4 miles downstream to the confluence with Anaconda Creek. Encompassing approximately nine acres of valley bottom, the Flossie-Louise Mine and Red Wing Mine are the dominant geographic features in Reach 3. The draft removal plan estimates removing approximately 43,000 cubic yards of tailings in Reach 3.

Reach 4 Upper Blackfoot River

Reach 4 begins at the confluence of Reach 3 Lower Beartrap Creek and Anaconda Creek and extends downstream past the water treatment plant to the confluence with Shaue (Shave) Gulch. In operation since 1996, the water treatment plant treats drainage from the Mike Horse adit and the combined discharges from an adit and shaft located at the Anaconda Mine near the confluence of the Blackfoot River and Anaconda Creek. Additional infrastructure in Reach 4 includes two stream crossings, Mike Horse Road that parallels the south side of the river corridor, and the Mary P. Mine and waste pile. Reach 4 includes 0.9 miles of the Upper Blackfoot River and approximately eight acres of riparian and floodplain area. The draft removal plan estimates removing approximately 139,000 cubic yards of tailings in Reach 4.

Reach 5 Middle Blackfoot River

Reach 5 includes the Middle Blackfoot River from the Shaue (Shave) Gulch confluence downstream to the wetland fen complex. Mike Horse Road parallels the north side of the river in Reach 5. The reach includes approximately 0.5 miles of channel and 13 acres of riparian and floodplain area. The draft removal plan estimates removing approximately 53,000 cubic yards of tailings in Reach 5.

Reach 6 Lower Blackfoot River Wetland Complex

Reach 6 includes the 71.5-acre wetland complex also referred to as the “Upper Marsh” in the UBMC Remedial Investigation Area (Tetra Tech, 2013a). The reach is characterized by reworked mine tailings deposits, beaver dams, a wetland mosaic including fen and marsh areas, and an anastamosed or multiple channel stream system. Presently DEQ is investigating sediment removal options in within the wetland complex, and removal quantities for Reach 6 have not been determined. Remediation alternatives being considered are described in Section 4.6.1 of this report.

1.6 Watershed Overview

The UBMC project area is located in Lewis and Clark County, Montana, approximately 15 miles east of Lincoln, Montana at the headwaters of the Blackfoot River (Figure 1-1). The Blackfoot River is one of the three major streams in the Helena National Forest (Sirucek 2001). The project area and the surrounding watershed is steep and forested with elevations ranging from 7,500 feet above mean sea level at the headwaters in the continental divide to 5,200 feet above mean sea level at the lower end of the UBMC project area at the confluence of Pass Creek and the Upper Blackfoot River (Stratus Consulting 2007, Hydrometrics 2007).

1.6.1 Climate

Pacific Ocean air masses that distribute rain in the western Montana mountain ranges influence climate in the Helena National Forest (Sirucek 2001). The National Oceanographic and Atmospheric Administration (NOAA) maintains two weather stations at Rogers Pass, approximately two miles northeast of the UBMC, and at the Lincoln Ranger Station, approximately fourteen miles west of the UBMC project area. Both weather stations show similar weather data that indicates relatively consistent climatic patterns throughout the Blackfoot River watershed. Based on temperatures recorded at the Roger’s Pass Station, January has the lowest average monthly minimum temperature at 13.4°F and July has the highest average monthly maximum temperature at 81.5°F. The record low is -70°F set on January 20, 1954 (Hydrometrics 2007). The area has average minimum temperatures near or below freezing from October to April (Stratus Consulting 2007). In the valley, summers are warm and receive high intensity, short duration thunderstorms. Wind speeds are highest in the spring (Sirucek 2001).

Average monthly precipitation ranges from 0.65 inches in February to 3.10 inches in June, with an average total annual precipitation of 24.15 inches. Figure 1-3 presents mean annual basin precipitation values and long term mean from 1895-2012 for the Blackfoot River at Meadow Creek. The dataset was developed using Parameter-elevation Regressions on Independent Slopes Model (PRISM) by Oregon State University affiliated climate groups.

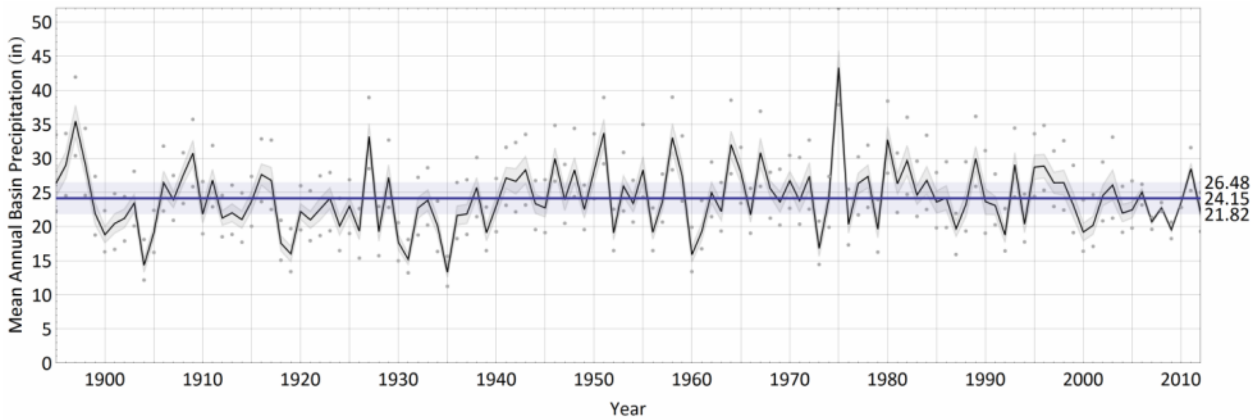


Figure 1-3. PRISM precipitation values and long term mean over the 1895-2012 base period for the Blackfoot River at Meadow Creek showing the annual and base-period mean, standard deviation, and minimum and maximum values within the watershed.

1.6.2 Vegetation

The vegetation communities within the UBMC riparian corridor and floodplain reflect altered hydrological and geomorphic processes resulting from historical mining activities. Riparian and wetland areas are found throughout the project area and include both shrub and forested community types. Riparian shrub communities are dominated by willows (*Salix* spp.) and alder (*Alnus viridis*) while forested riparian areas are dominated by conifers including lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*), or deciduous trees such as quaking aspen (*Populus tremuloides*). Portions of the riparian area in all reaches include unvegetated areas where contamination levels are either too high or tailings are too thick for vegetation to establish. Reaches 5 and 6 are considerably wetter than Reaches 1 through 4 and include several wetland communities consisting of emergent marsh, fen, shrub, and forested wetland types. Most of the wetlands are located at the downstream end of the project area (Reach 5 and 6).

Plant species composition on slopes adjacent to and surrounding the UBMC project area are primarily influenced by aspect. South and west facing slopes are drier and consist of open, mixed Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine forest with an understory of common juniper (*Juniperus communis*), Idaho fescue (*Festuca idahoensis*), elk sedge (*Carex geyeri*) and bluebunch wheatgrass (*Pseudoroegneria spicata*). North and east facing slopes are generally more mesic and consist of lodgepole pine, Douglas-fir, Engelmann spruce and subalpine fir. Understory species on north and east facing slopes include beargrass (*Xerophyllum tenax*), and dwarf bilberry (*Vaccinium cespitosum*).

Existing vegetation communities were delineated during the 2012 and 2013 growing seasons in order to describe plant communities and identify wetland locations. During field visits, the extents of distinct vegetation communities were delineated over aerial photographs. Within each identified vegetation community, species lists were generated and information on topography and hydrology was collected at representative locations within each vegetation community. A global positioning system (GPS) point was recorded and photographs were taken at each location where data were collected. Based on this information, descriptive plant community categories were developed according to dominant plant species composition and life form, geomorphic position, visible tailings, level of disturbance, and presence of bare ground. A total of 21 existing vegetation cover types were delineated for the UBMC Reaches 1 through 6, described in Section 2.5 of this report. Detailed descriptions of each existing vegetation cover type with associated plot data and photographs are included in Appendix D.

1.6.3 Geology

The UBMC project area lies within the Northern Rocky Mountain physiographic province (Fenneman and Johnson 1946) with mountain ranges and valleys trending in a general northwest to southeast direction (Sirucek 2001). Landforms within the Helena National Forest are a result of water and ice deposition as well as erosion. Glacial influences in some areas have left U-shaped valleys, cirques, steep sided mountain peaks and rolling glacial moraines. In areas such as the UBMC project area, streams have eroded V-shaped mountain valleys, terraces and floodplains (Sirucek 2001). The mountain ranges in the Helena National Forest are folded and faulted metasedimentary rocks and limestone. The three main bedrock units found in the UBMC are 1) the Belt Series Spokane Formation, 2) a diorite sill, and 3) a series of igneous intrusive bodies from the Tertiary-age.

The steeper drier mountain slopes close to the river are composed of volcanic material, while the wetter higher slopes are part of the Spokane Belt Series and composed of metasediment. The floodplain consists of sandy to clayey coarse alluvial material with rounded rock fragments (Hydrometrics 2007, Sirucek 2001). Breaklands (steep, high relief slope areas) that consist of rock outcrops and deliver high volumes of sediment are located within a mile of the southern portion of the Blackfoot River on both the east and west sides of the river. The breaks follow along the eastern side of the river but increase in distance from the river in the northern sections (Sirucek 2001).

In the western area of the Helena National Forest where the UBMC project area is located, granite rocks intrude limestone and metasedimentary rocks (Sirucek 2001). The metasedimentary rocks of the Spokane Formation are often weakly weathered and moderately to highly fractured (Sirucek 2001). Weathering of this material creates angular rock fragments ranging in size from moderately coarse to moderately fine texture material. Soil resulting from this material is at a slight hazard for erosion (Sirucek 2001).

In the center of the watershed, igneous intrusive stocks composed of quartz Tertiary monzonite porphyry are found within the Spokane argillite and diorite sill. Dikes formed radially from the main center stock along faults and fractures. These radial dikes were the original target for mining in the area (Hydrometrics 2007). Mineralization related to this Tertiary-age intrusive complex imposes natural constraints on remediation and restoration that will need to be considered as specific project objectives are developed during later design phases.

Granitic rock intrusions such as those distributed throughout the UBMC project area are weakly to moderately jointed and weathered. When only weakly weathered, the hardness of this bedrock can limit excavation indicating underlying stability. Underlying geomorphology influences stream channel locations and slope gradients and shape depending on the hardness and orientation of bedrock. Erosion hazard is severe in soil derived from granites (Sirucek 2001).

1.6.4 Soils

Three main soil map units are present in the UBMC project area: 1) Aquolls, 2) Typic Cryoboralf, and 3) Typic Ustochrepts-Typic Cryochrepts complex. Volcanic material is also found in the UBMC project area as deposits from the eruption of Mount Mazama, Oregon about 6,700 years ago. Soils following the river channel are Aquolls, found on floodplains and terraces and formed in alluvium or glacial outwash. The soil is usually characterized by an organic layer 2 to 16 inches thick with substratum layer that includes a cobbly sandy clay loam for up to 60 inches or more. Water tables in these soils are near or at the surface during the spring and the beginning of summer, while spring snowmelt can cause short flooding periods. Underlying valley fill material is characterized by stratified alluvial deposits and glacial outwash (Sirucek 2001).

The north-facing, mountainous slopes along the south side of the Upper Blackfoot River channel are Typic Cryoboralf soils. The soil is medium to moderately fine textured and covers the bedrock with 40 to more than 60 inches. Subsoils contain 40 to 60 percent angular rock fragments. The bedrock consists of argillites, siltites and quartzites with dikes and sills of andesites. Andesites are often associated with landslides and practices causing erosion are discouraged. This form of weathered bedrock forms loamy material (Sirucek 2001).

On the south-facing mountainous slopes along the north side of the Upper Blackfoot River channel the soils are Typic Ustochrepts-Typic Cryochrepts complex. The surface layer of these soils has a medium texture reaching 20 to 40 inches deep above the bedrock. Because they are southerly facing, these soils are warm and dry as opposed to the cool and moist soil of northerly facing soils. Beneath the soils lies bedrock of argillites, siltites and quartzites. Some sandstones and shales also exist. When weathered, the sandstones and shales also produce a loamy material. These soils are not highly susceptible to erosion, but can be difficult to revegetate because of a lack of water holding capacity (Sirucek 2001).

Although not in direct contact with the Upper Blackfoot River, Typic Cryoboralfs-Typic Cryochrepts complex soils are found on the north facing slopes of Anaconda Creek, a tributary to the Upper Blackfoot River flowing west. These soils have surface layers two to seven inches thick that formed in loess (accumulations of wind-blown fine textured silts or sediment) influenced by volcanic ash with a medium texture. Subsoils have 40 to 60 percent angular rock fragments and the volume of clay in the soil increases on lower portions of the slope. Underlying bedrock is the same as that of the soils on the south facing slopes, Typic Ustochrepts-Typic Cryochrepts complex and erosion is not prominent (Sirucek 2001).

1.6.5 Hydrology and Water Quality

The UBMC project area is located in the headwaters of the Blackfoot River where numerous perennial and intermittent streams contribute to the combined flow of the Upper Blackfoot River. The project area is comprised of eight ungaged sub-watersheds draining a catchment area of approximately 13.4 mi^2 with elevations ranging from 5,160 feet above mean seal level (a.m.s.l.) at the confluence of Meadow Creek and the Upper Blackfoot River, to 7,500 a.m.s.l. at the Beartrap Creek watershed divide. A majority of the watershed originates on the Helena National Forest. Major tributaries in the project area include Beartrap Creek, Mike Horse Creek, Anaconda Creek, Stevens Gulch, Shave Gulch, Paymaster Creek, and Pass Creek. The Upper Blackfoot River forms at the confluence of Beartrap Creek and Anaconda Creek in the middle of the project area.

Similar to headwater systems located in intermediate to high elevation regions of the northern Rocky Mountains, tributaries draining the UBMC project area are subject to rain-on-snow driven storm events that can produce floods of significant magnitude. Snowmelt and spring storm events recharge the local groundwater aquifers which in turn sustain baseflows in the project area streams.

All surface waters within the UBMC project area are classified as B-1 waters (ARM 17.30.607) with the following identified beneficial uses (MT DEQ 2003): 1) growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; 2) contact recreation; 3) agriculture water supply, 4) industry water supply, and 5) drinking, culinary and food purposes after conventional treatment (Tetra Tech 2008).

The Upper Blackfoot River (above Landers Fork), Beartrap Creek, and Mike Horse Creek are listed on DEQ's 303(d) list as having impaired beneficial uses for aquatic life, cold water fish, and drinking water supply. Beneficial uses are identified as impaired due to the following pollutants of concern for the Upper Blackfoot River and Beartrap Creek: cadmium, copper, iron, lead, manganese, and zinc; with the addition of aluminum for Mike Horse Creek. These pollutants are released from areas of historical mine activities and may be related, in part, to natural background conditions (Tetra Tech 2008).

1.6.6 Watershed Processes

Streams and their associated riparian areas are open ecosystems that are linked longitudinally, laterally, and vertically by both hydrological and geomorphic processes (Newbold et al. 1981, Vannote et al. 1980). The channels and floodplains that comprise the UBMC watershed network are dynamic and have adjusted over time to local and watershed-level changes in discharge, sediment supply, debris input, riparian vegetation conditions, and in particular, the dam failure flood (breach) event in 1975.

Longitudinally, the UBMC stream reaches are connected through sediment transport where sediment originating from upland slopes in Reach 1 discharges into headwater streams and is then transported downstream through Reaches 3 and 4 to Reaches 5 and 6 where it accumulates in a deposition zone (Figure 1-4). The Mike Horse Tailings Impoundment has created a discontinuity in sediment transport and supply between Reach 2 Upper Beartrap Creek and Reach 3 Lower Beartrap Creek. Unvegetated steep valley walls bordering Mike Horse Creek and the breached dam on Beartrap Creek still appear to contribute large sediment loads that are transported by Beartrap Creek and deposited downstream into the Blackfoot River and its floodplain. Runoff from both abandoned and active roads, as well as tributaries with contaminated sediments like Paymaster Creek, contributes additional sediment to the system. Deposited contaminated sediment has accumulated in Reaches 5 and 6 of the UBMC causing floodplain elevations to increase and channels to become entrenched. Channel aggradation is caused by an increase in sediment supply that exceeds the transport capacity of the channel.

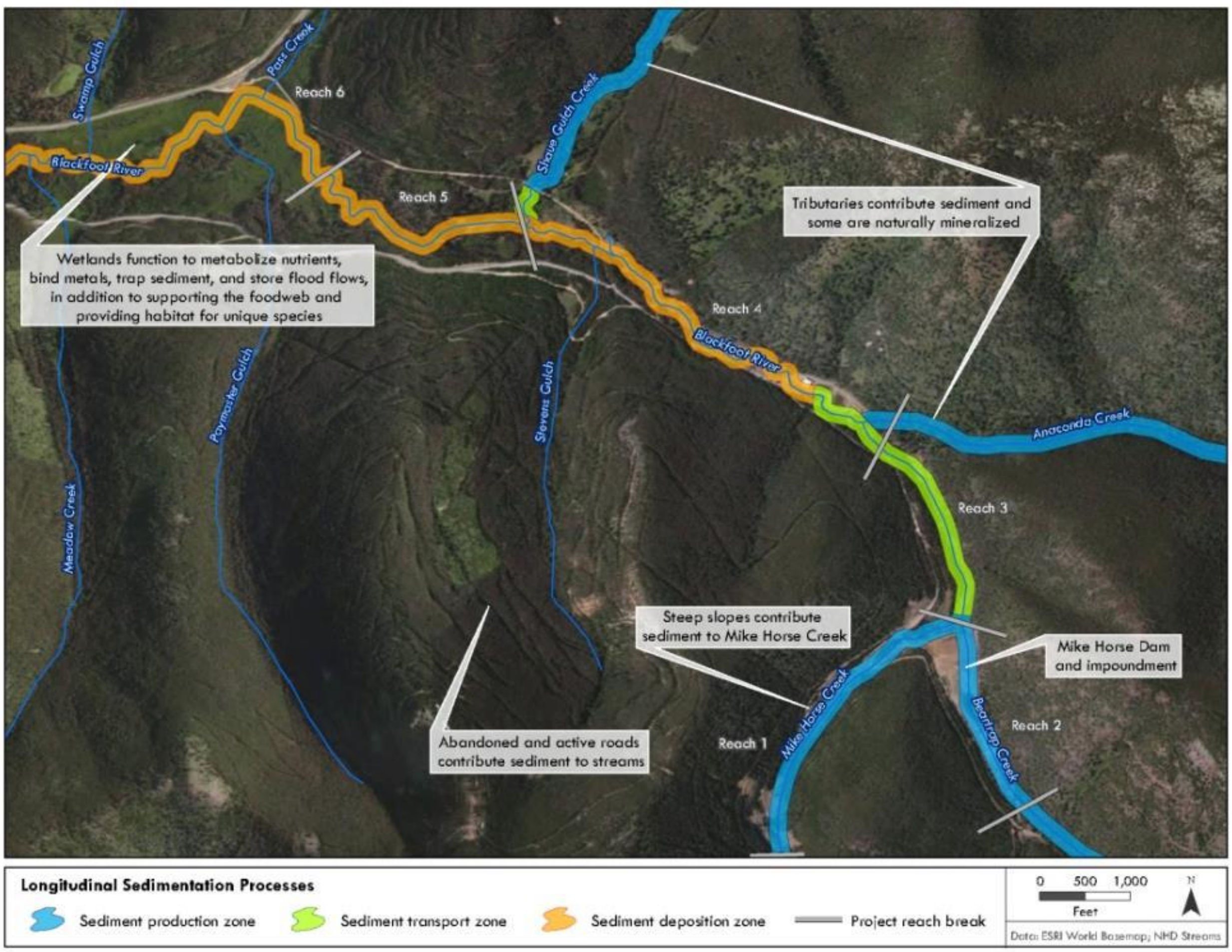


Figure 1-4. Conceptual model illustrating longitudinal ecological processes in the UBMC project area.

Aggradation of the floodplain is natural in Reaches 5 and 6 where many years of sediment deposition has partially contributed to the natural development of the broad wetland complex located in Reach 6. However, mining related deposition has accelerated the rate of floodplain aggradation resulting in a higher floodplain relative to the channel. Accumulated sediments in the floodplain can eventually reduce the vertical connection between surface water and groundwater. Surface water and groundwater interactions promote the cycling of nutrients which is important to both the productivity of the stream and riparian area. Floodplain aggradation can also lead to the disconnection of riparian vegetation root systems from groundwater therefore altering vegetation presence and abundance. Currently, portions of the UBMC floodplain consist of areas of bare ground where contamination levels are either too high or too deep for vegetation to persist. The loss of riparian vegetation leads to reduced ecological functions typically provided including trapping sediments, stabilizing creek banks, promoting organic matter, helping to regulate stream temperatures through shading, contributing food for microorganisms and aquatic insects, and providing important wildlife habitat. In addition, riparian plants reduce erosive energy and increase the time for water to infiltrate the soil and be stored for slow release back into the stream. However, stream channel and floodplains that are disconnected vertically lose these important ecological functions.

Elevated floodplain surfaces and channel entrenchment in Reach 5 has resulted in the loss of lateral surface water connection with the channel. Reducing floodplain connectivity affects both biological and chemical processes in both the river and the floodplain. Connected floodplains allow natural riverine processes to occur and provide beneficial ecological functions including energy dissipation, sediment deposition, water retention, nutrient cycling, and periodic flooding of riparian vegetation. Floodplains are developed over time as the result of flooding. Water moving over a floodplain travels at a lower velocity than the channel flow, and as flow velocity decreases, sediment is deposited. Deposits of sediment create layers of depositional material on the floodplain and contribute important nutrients to riparian areas. However, if a channel is no longer able to access its floodplain it no longer can provide these beneficial functions.

The longitudinal connectivity of streams is often punctuated by beaver dams which increase heterogeneity by creating a stepped channel bed profile with shallower gradients, slower velocities, increased sediment deposition behind the dams and increased scouring downstream. In addition, beavers are capable of modifying the landscape at a watershed scale by maintaining floodplains, scouring additional channels, and causing channel avulsions (Burchsted et al. 2010). In the UBMC, there are a series of beaver dams on the Blackfoot River within a broad wetland complex in the lower end of Reach 5 and throughout Reach 6 downstream to the Meadow Creek confluence. The beaver dams are in different stages of evolution ranging from active, inactive, to breached. For example, the large wetland complex in Reach 6 is partially a 'beaver meadow' that has formed after a beaver dam was breached and flows became confined within a defined channel formed in the sediments that were impounded behind the dam. The channel forms through headward progressing erosion that begins at the dam breach and continues to cut downward into unconsolidated sediments with near vertical banks (Burchsted et al. 2010). The effects of a breached dam are often localized and buffered by the surrounding beaver meadow and other beaver dams that are in varying stages of development. An abandoned dam can persist for decades before being fully breached and completing the transition from pond to beaver meadow. Beaver meadows transition from young and wet to old and moist (Naiman et al. 1994). Older beaver meadows typically convert to permanently saturated wetlands that can persist for centuries to millennia (Naiman et al. 1988). Naiman et al. (1988) found that vegetative succession around beaver ponds was complex in the boreal forest of Minnesota, Quebec, and Alaska where the formation of emergent marshes, bogs, and forested wetlands appear to persist in a stable condition for centuries.

The large wetland complex in Reaches 5 and 6 includes areas of open water, emergent marsh, fen, scrub shrub, and paludified forest wetland systems. The hydrology of these wetlands appears to be influenced by both beaver dams and groundwater discharge from adjacent hillslopes. Fens are of particular interest because they are a unique wetland ecosystem that has perennially saturated soils attributed to constant groundwater inflow, and provide a critical refugium for many plant and animal species specifically adapted to this wetland type. Permanently saturated conditions allow for the accumulation of organic matter that leads to the development of peat. The slow rate of peat accumulation of approximately 8 inches every 1,000 years indicates that UBMC fens have been developing for many thousands of years and are therefore exceptionally vulnerable to disturbances. Paludified forests are often found adjacent to fens where fen adapted plant species, including *Sphagnum* spp., colonize due to rising water levels. This large wetland complex is ecologically significant because of its functions including maintenance of water quality, ground water discharge sites, surface and ground water flow regulation, water storage, and providing critical habitat for many plants and wildlife. In addition, fens have an increased ability to sequester heavy metals through the uptake of vegetation and adsorption by high organic content soils. These wetlands are also important due to their location longitudinally within this headwater system because they are capable of attenuating sediments transported from upstream and reducing the further transport of contaminated sediments downstream.

1.6.7 Fisheries and Aquatic Habitat

The integrity of aquatic communities plays an essential role in supporting ecological function in the upper Blackfoot watershed. Functions of the aquatic biota include: 1) primary and secondary productivity, 2) nutrient cycling and transport of energy/food to organisms downstream, 3) food for fish, birds and higher food-chain animals, 3) security cover for birds and their supporting ecosystems, 4) indicators of a functioning ecosystem, 5) biodiversity, and 6) recreational and cultural services (Stratus Consulting 2007). Due primarily to mining-related contamination, the ecological integrity of biotic communities within the Upper Blackfoot River environment has been greatly compromised within and downstream of the UBMC (Ingman et al. 1990, Moore et al. 1991, Stratus Consulting 2007). The Upper Blackfoot River and Beartrap Creek are 303(d) listed streams for a variety of impairments including tailings, resource extraction, habitat modifications, and bank and shoreline modifications/destabilization (The Blackfoot Challenge et al. 2005). The failure of the Mike Horse Mine Dam in 1975 specifically led to 1) the local collapse of the westslope cutthroat trout population (Spence 1975), 2) the contamination of the valley bottom and 3) the downstream transfer of heavy metals and the uptake of heavy metals into the aquatic food web (Ingman et al. 1990, Moore et al. 1991, Stratus 2007). Thirty years after the Mike Horse Dam failure, mining contamination and related disturbance continue to impede cutthroat trout from re-establishing in the Upper Blackfoot River environment (Stratus Consulting 2007, Pierce et al. 2008). Westslope cutthroat trout is a Species of Special Concern in Montana and the focus of recovery actions in other areas of the Blackfoot basin over the last 20 years. Compared to other species, westslope cutthroat trout appear to hold the highest potential for recovery within disturbed areas through successful removal of contaminants and the restoration of essential stream and riparian habitats.

Where not directly affected by past mining, streams both up- and downstream of the UBMC area continue to support communities of resident westslope cutthroat trout and sculpin (*Cottus* spp.). These species inhabit small headwater streams like Anaconda Creek and Shaue (Shave) Gulch. In these and other headwater streams of the Upper Blackfoot River, westslope cutthroat trout maintain a high level of genetic purity (Pierce et al. 2008). Westslope cutthroat trout also inhabit and reproduce in the mainstem of the Upper Blackfoot River downstream of the UBMC, although the abundance of westslope cutthroat trout has declined since the collapse of the Mike Horse tailings dam (Stratus Consulting 2007). Westslope cutthroat trout in the Upper Blackfoot River still possess a migratory component to the population (Pierce et al. 2007, 2008). The migratory fish move downstream as juveniles, mature in the larger streams and rivers and then return as adults to spawn in their natal streams. Adult spawners are known to migrate distances of up to 40 river miles up the Blackfoot River to spawn. Because the Upper Blackfoot River supports both resident and migratory fish, it is crucial to maintain passage and restore suitable habitats in order to recover and maintain westslope cutthroat trout populations and life history variation affected by past mining activities.

In addition, native bull trout and mountain whitefish (*Prosopium williamsoni*) also occupy the Upper Blackfoot River downstream of the UBMC in low abundance (Status 2007, Pierce et al. 2008). Bull trout are a Montana Species of Concern and a listed threatened species under the Federal Endangered Species Act. The portion of the Upper Blackfoot River below the UBMC project area is regarded as a recovery area for bull trout and was designated critical habitat for bull trout by the U.S. Fish and Wildlife Service (FWS) in September 2010 (USFWS 2010). Habitat requirements, or primary constituent elements (PCEs), necessary to recover critical habitat included:

- Springs, seeps, groundwater sources, and subsurface water connectivity to contribute to water quality and quantity and provide thermal refugia;
- Migratory habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats;
- An abundant food base;

- Complex river, stream and aquatic environments and processes with features such as large wood, side channels, pools, undercut banks and substrates, to provide a variety of depths, gradients, velocities and structure;
- Water temperatures ranging from 2 to 15 ˚C (36 to 59 ˚F);
- Substrates of sufficient amount, size and composition to ensure success of egg and embryo overwinter survival, fry emergence, and young-of-the-year and juvenile survival;
- A natural hydrograph, including peak, high, low and base flows within historic and seasonal ranges;
- Sufficient water quality and quantity; and
- Few nonnative predatory or competitive species present.

Montana Fish, Wildlife and Parks (MFWP) rely on the 'wild trout' philosophy to manage stream dwelling salmonids in Montana. High quality spawning and rearing habitat and stream connectivity all serve as the basis of this management philosophy. Generally, MFWP defines quality stream habitat as streams with sufficient water quantity and quality and an arrangement of physical channel features that provide food, cover and space that allow a population to thrive. Cold, clean and connected waters and the natural complexity of stream channels are all essential to allow fish movement among streams or reaches to access the variety of habitats required to complete their life-cycle (Pierce 2010).

In addition to native salmonids, non-native brown trout (*Salmon trutta*) and brook trout (*Salvelinus fontinalis*) are also present in the upper Blackfoot River watershed. Brown trout are considered rare in tributaries of the upper Blackfoot River upstream of Lincoln and their population abundance is very low (<5% of trout community) in the upper Blackfoot River downstream of UBMC. Brown trout abundance increases in the down-river direction. Compared to brown trout, brook trout abundance is higher in the upper river tributaries, including stream supporting westslope cutthroat trout, particularly in the lower stream reaches. As an example, westslope cutthroat trout comprise >98% of the trout community in Anaconda Creek and brook trout comprise 2% of the trout community. Brook trout comprise >60% of the trout community in the Blackfoot River downstream of UBMC (R. Pierce, Montana Fish, Wildlife & Parks, personal communication).

Macroinvertebrates found in the UBMC project area include predominantly stoneflies, mayflies, and caddisflies as well as true flies and aquatic beetles. Like fish, macroinvertebrates require clean water and passage across stream reaches. Both downstream drift of juvenile macroinvertebrates from streams like upper Beartrap Creek and Anaconda Creek will help colonize the restored stream reaches. In addition, upstream aerial recolonization will occur by winged adults following clean-up once the stream habitat is restored to suitable conditions.

In conjunction with the Blackfoot Challenge and other partners, MFWP developed a Basin-Wide Restoration Action Plan for the Blackfoot Watershed (Action Plan) in 2005. The Action Plan integrates all the stream and native fish restoration efforts in the Blackfoot River watershed and provides a comprehensive, native fish-based, priority-driven template for restoration projects. Further, the Action Plan expands upon the gains of the existing Blackfoot River Restoration Program (The Blackfoot Challenge et al. 2005). The basin-wide strategy focuses on tributary restoration as a means to restore the watershed on a comprehensive level as wild trout depend on the connectivity of the mainstem and its tributaries to complete their life histories. With an emphasis on improving tributary conditions, native trout of the Blackfoot River have shown consistent population size increases since native fish recovery efforts began in 1990 (The Blackfoot Challenge et al. 2005).

Although Mike Horse Creek, Beartrap Creek, and Anaconda Creek are not covered in the Action Plan, the Upper Blackfoot River is considered a High Priority for the pursuit of native fish restoration activities (Pierce et al. 2008). The classification is based on the presence of migratory native bull trout and cutthroat trout and the potential of the Upper Blackfoot River to provide for downstream fisheries improvements through restoration activities. At this time, the UBMC also lacks the riparian vegetation and physical channel conditions necessary to provide and maintain native trout habitat. Successful remedial activities combined with the reconstruction of natural channels, complex habitat features, and full vegetative recovery will be necessary to recover the coldwater fishery from mining disturbance.

2 Design Investigations

This section describes the various investigations completed to develop the design criteria presented in Section 3 of this report. Investigations were conducted over a four-year period from 2010 through 2013.

2.1 Channel Forming Discharge and Flood Frequency Analysis

This section describes the investigations used to generate hydrologic estimates of bankfull discharge and flood frequencies for all sub-watersheds and cumulative watershed areas (coinciding with major tributary confluences and reach breaks) in the project area. As described in Section 1.6.5 of this report, the UBMC is comprised of eight ungaged sub-watersheds draining a catchment area of approximately 13.4 mi^2. This analysis was performed to support development of the channel and floodplain design criteria presented in Section 3 of this report.

2.1.1 Channel Forming Discharge

Methods

Channel and floodplain restoration plans for UBMC are being designed to accommodate a wide range of streamflow and sediment conditions. A restoration objective is to design and construct a dominant channel that hydrologically interacts with the floodplain at the incipient point of flooding. For the purpose of restoration planning in the UBMC project area, the channel-forming discharge is considered to be morphological bankfull (Charlton et al. 1978, Andrews 1983, Hey and Thorne 1986). Because regional regression equations are not available for estimating bankfull discharge, alternative methods were utilized as described in this section.

Bankfull discharge was estimated for eight locations in the UBMC project area (Figure 2-1). At each reach, multiple channel cross-sections were surveyed to characterize the morphology of the bankfull channel. A longitudinal profile was completed to compute the water surface and bankfull energy gradients along nominal reach lengths equal to 20 times the bankfull channel width, or two meander wavelengths, whichever was greater. The cross-sections and longitudinal profiles were surveyed using a survey-grade GPS and Topcon GTS 312 Total Station. Wolman pebble counts were completed to characterize the surficial particle size distribution and channel roughness. Stream discharge was measured to calibrate the stream flow at the time of the field survey to observed water surface elevations.

The range of channel forming or bankfull discharges was estimated using two methods. The first method utilized HEC-RAS version 4.1.0 (USACE 2010), a one-dimensional model, calibrated to the measured low flows; models were run over a range of discharges. The resulting water surface profiles were compared with surveyed geomorphic bankfull indicators to identify the range of potential discharges that intersect the surveyed bankfull profile.

The second method utilized the Limerinos equation (1970) for relative roughness. This method utilized the measured bed material size and hydraulic depth to estimate roughness values. Roughness value estimates were developed for the range of observed bankfull stages at each of the sites. An iterative approach was utilized to estimate a representative roughness value for the range of observed bankfull indicators and corresponding discharges.

Hydraulic models were not developed in Reach 3 and Reach 5 of the project area due to the impaired river morphology and lack of reliable field geomorphic indicators. Estimates for Reach 3 and Reach 5 were derived by adding the values for Reach 1 Mike Horse Creek and Reach 2 Upper Beartrap Creek for Reach 3, and the values for Reach 4 Upper Blackfoot River and Shaue (Shave) Gulch for Reach 5.

Results

Results applying the Limerinos equation are summarized in Table 2-1. The range of discharges estimated using the Limerinos equation likely represents a more realistic range of discharges than those estimated using the calibrated low-flow roughness values. The hydraulic depths for the model calibrated to low-flow conditions are lower than the hydraulic depth estimated for the lowest flows of the envelope curve produced using the Limerinos equations. This suggests that the roughness values for the low-flow calibration are outside of the range of roughness values that would be considered reasonable for the range of channel forming discharges modeled.

The estimated bankfull discharge for Reach 6 using the Limerinos equation and best fit line to observed geomorphic indicators is low considering the additional contributing drainage area from Paymaster Gulch and Pass Creek (0.58 mi^2 and 2.34 mi^2, respectively). A more realistic estimate is the value derived based on model calibration to the observed high bankfull indicators.

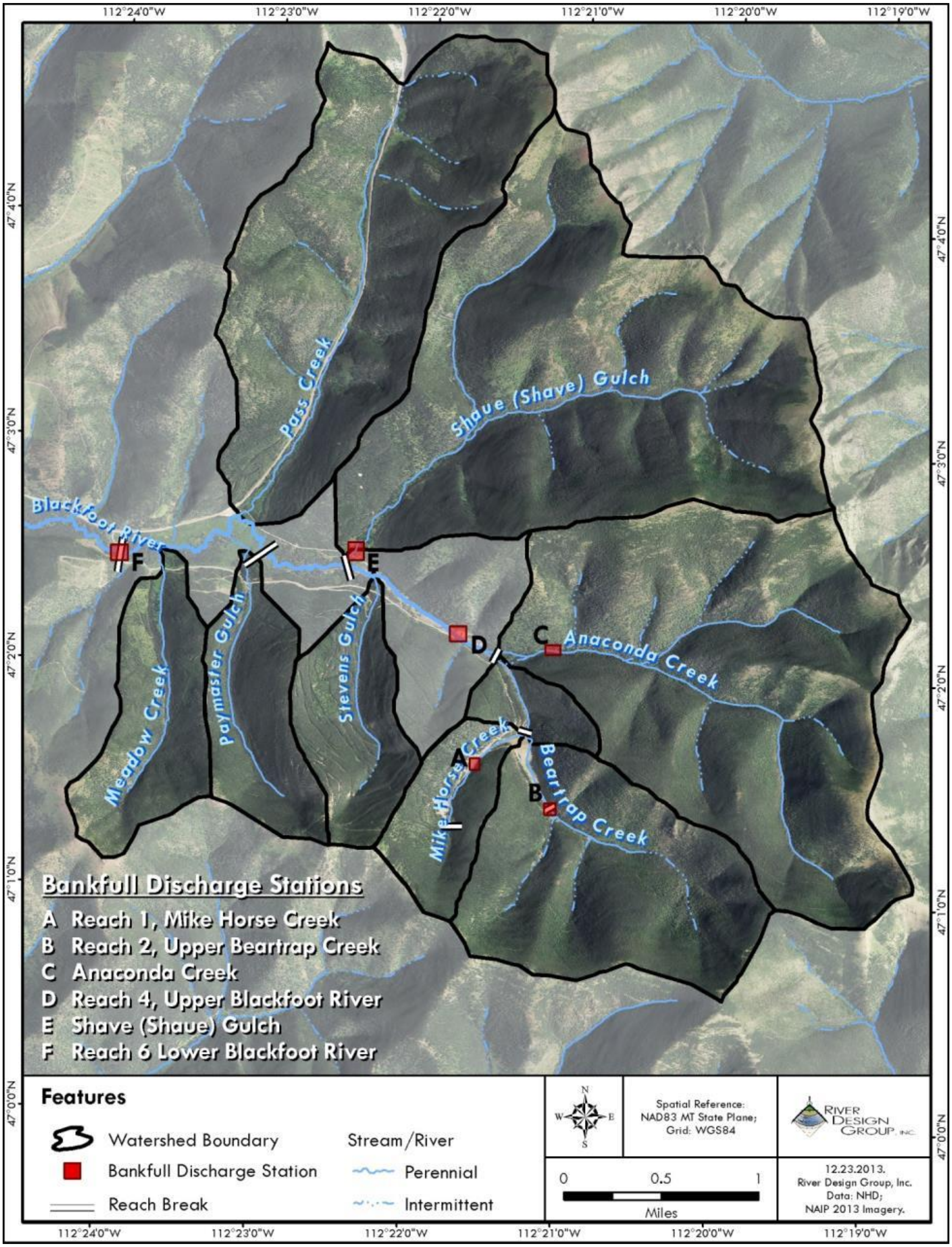


Figure 2-1. UBMC sub-watershed boundaries and bankfull discharge modeling stations.

Table 2-1. Bankfull discharge modeling results.

Site	Qbf (Low)	Qbf (High)	Q (best fit)
Reach 1 Mike Horse Creek	14	18	16
Reach 2 Upper Beartrap Creek	14	40	25
Reach 3 Lower Beartrap Creek	28	58	41
Anaconda Creek	30	125	55
Reach 4 Upper Blackfoot River	70	125	90
Shaue (Shave) Gulch	30	110	55
Reach 5 Middle Blackfoot River	100	235	145
Reach 6 Lower Blackfoot River	120	180	150

2.1.2 Flood Frequency Analysis

Methods

Flood frequency estimates for the eight ungaged sub-watersheds within the UBMC were calculated using equations described in *Water Resources Investigation Report 03-04308: Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998* (USGS 2004). The equations were derived using standard regression techniques and correlate flood frequency estimates from long-term streamflow gaging stations with watershed metrics over statewide physiographic regions. The regions as delineated by the United States Geological Survey (USGS) were selected to ensure similar climatic and physiographic regions. The UBMC study area is unique in that it occurs very near the continental divide within a relatively large, ungaged area of the Northwest Region, but also near the boundary of three physiographic regions, as shown in Figure 2-2.

The primary difference between the West Region and Northwest Region equations is that while both use drainage area and mean annual precipitation to estimate flood frequency, the West Region also includes the percent forest cover as a predictor which essentially functions as a dampening factor. Although the UBMC study area is technically located within the Northwest Region, considering that the Upper Blackfoot River drains into the West Region, which includes the closest Blackfoot River gages, equations from both regions were evaluated for comparative purposes. Table 2-2 summarizes watershed statistics for UBMC sub-watersheds.

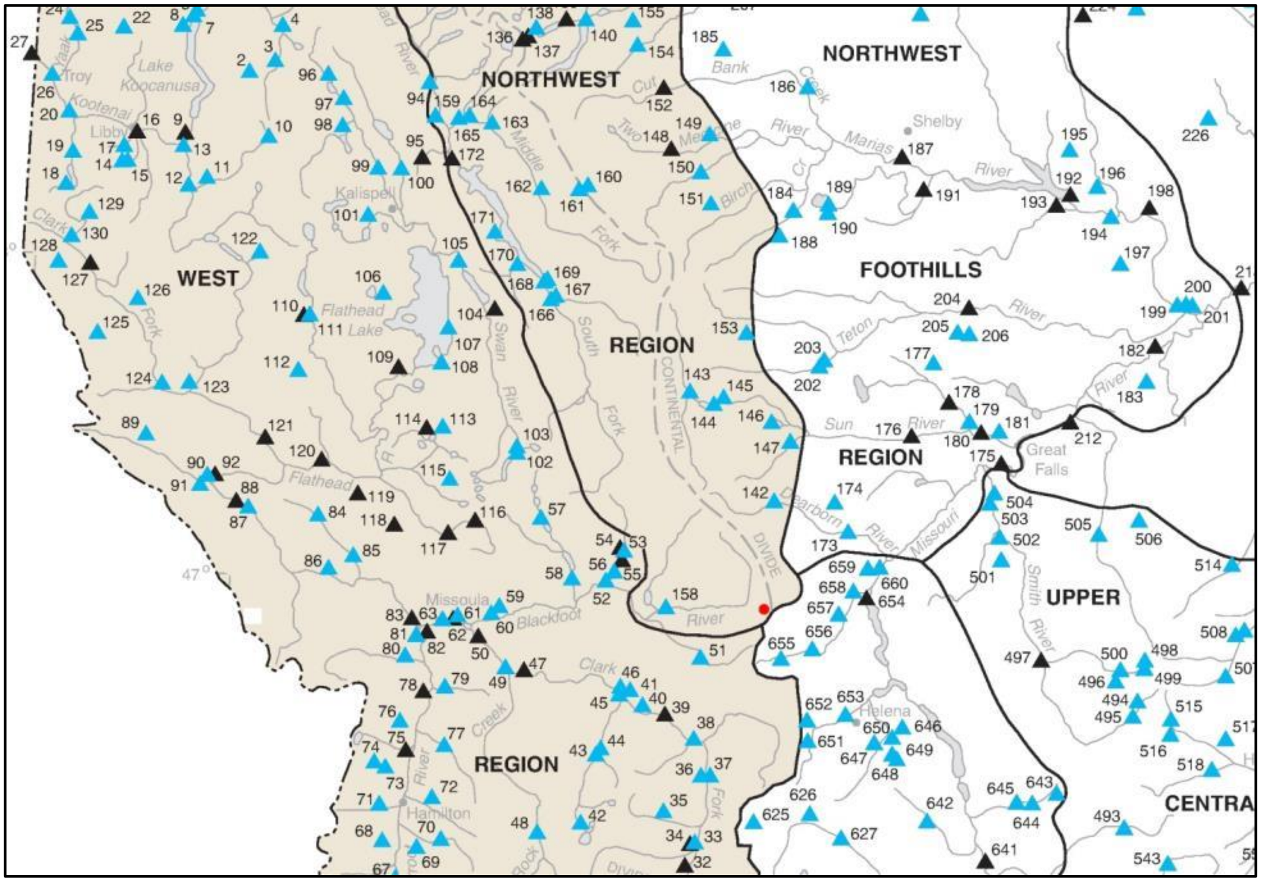


Figure 2-2. Physiographic regions and gaging stations as identified in WRIR-03-4308. The UBMC study site is shown as a red dot.

Table 2-2. UBMC watershed characteristics including drainage area, mean annual precipitation, and percent forest cover.

Watershed	Area (mi^2)	Mean Annual Precipitation (in)				% Forest Cover
		1895-2012	1981-2010	1971-2000	1961-1990	
Mike Horse Creek	0.41	22.14	28.42	21.99	25.70	92
Beartrap Creek[1]	1.42	27.18	29.78	22.25	29.05	79
Beartrap Creek[2]	2.01	25.92	29.02	22.18	27.97	82
Anaconda Creek	2.92	26.97	29.62	22.39	28.15	83
Stevens Gulch	0.55	21.21	28.61	21.93	24.01	93
Shaue (Shave) Gulch	3.30	24.29	29.96	23.51	24.85	87
Pass Creek	2.34	22.62	29.20	23.29	23.83	88
Paymaster Creek	0.58	21.17	27.81	21.93	23.24	97
Meadow Creek	0.66	21.02	27.61	21.98	22.60	92

[1] from watershed divide to confluence with Mike Horse Creek
[2] from watershed divide to Anaconda Creek

Results

Flood frequency estimates were calculated using the equations presented in WRIR-304308, as discussed above. As illustrated in Figure 2-3 below, the variability in the estimates from the five precipitation datasets decreases with exceedance probability and is generally bracket by a prediction interval of less than 50 percent.

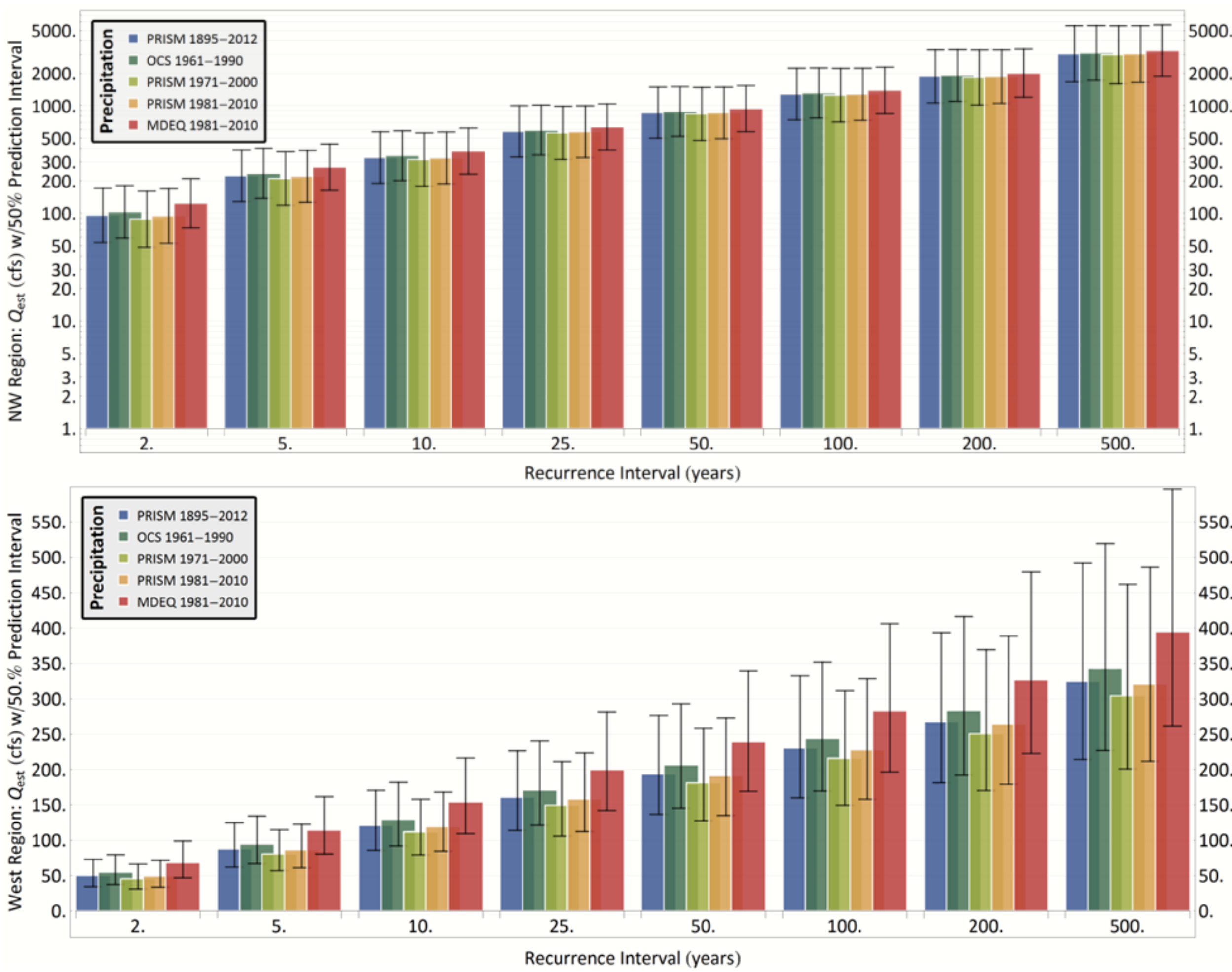


Figure 2-3. Flood frequency estimate for the Blackfoot River at Meadow Creek based on the Northwest and West Region equations with 50 percent prediction intervals.

Results indicate that the Northwest Region equations predict much larger flood frequency estimates than the West Region equations which include a dampening factor correlated with percent forest cover. Noting the large discrepancy between the predicted flood frequency values for the two regions compared, the recommendation is to proceed with the more conservative values represented by the Northwest Region equations using the 117-year PRISM precipitation dataset, which was found to be within the range of the other 30-year base period datasets. Flood frequency analysis results are summarized in Table 2-3.

Table 2-3. Northwest Region flood frequency results based on PRISM data from 1895-2012 for primary sub-watersheds and tributary junctures.

Watershed	Recurrence Interval (yrs)					
	Q2	**Q5**	**Q10**	**Q25**	**Q50**	**Q100**
Mike Horse Creek	3.4	10.7	18.5	38.7	64.0	103.7
Beartrap Creek[1]	14.3	37.3	58.6	111.0	175.2	273.6
Beartrap Creek[2]	18.4	47.9	75.0	191.4	455.1	676.6
Anaconda Creek	27.4	68.2	104.3	191.4	296.3	455.1
Stevens Gulch	4.3	13.3	23.0	47.9	78.9	127.1
Shaue (Shave) Gulch	26.6	68.5	106.7	199.0	309.3	475.7
Pass Creek	17.7	47.9	77.0	148.1	233.4	362.9
Paymaster Creek	4.5	13.7	23.6	49.2	80.9	130.3
Meadow Creek	5.0	15.4	26.4	54.7	89.5	143.8
BFR at Anaconda Creek	43.3	104.7	157.4	282.7	432.0	656.0
BFR at Stevens Gulch	49.8	120.2	180.9	324.4	494.3	478.2
BFR at Shaue (Shave) Gulch	72.8	171.4	254.6	448.9	676.7	1014.8
BFR at Pass Creek	91.6	213.7	316.0	552.9	828.5	1235.6
BFR at Paymaster Creek	77.2	181.8	269.9	475.3	715.5	1071.5
BFR at Meadow Creek	96.0	223.5	330.4	577.4	864.2	1287.3

[1] from watershed divide to confluence with Mike Horse Creek; [2] from watershed divide to Anaconda Creek including Mike Horse Creek

2.2 Channel Morphology

This section describes the geomorphic investigations used to develop channel design criteria. A hierarchical stream channel classification system developed by Rosgen (1996) was employed to quantify the morphological relations and predict the most probable form of the channels and floodplains in the UBMC project area. Table 2-4 provides a summary of the valley types and existing and potential stream types in the project area.

Table 2-4. Valley types and potential and existing stream types in the UBMC project area.

Reach	Valley Type	Potential Stream Type(s)	Existing Stream Type(s)
Reach 1 Mike Horse Creek	II	A2	G3
Reach 2 Upper Beartrap Creek	II	B2	N/A
Reach 3 Lower Beartrap Creek	II	B3	D4
Reach 4 Upper Blackfoot River	II	B3c → C3	D4
Reach 5 Middle Blackfoot River	VIII	C3 → C4 → E4	C4 → D4
Reach 6 Lower Blackfoot River	XI	Anastomosed	Anastomosed
Anaconda Creek	II	B3	B3
Shaue (Shave) Gulch	II	B4	F4

The *Conceptual Restoration Plan for the Upper Blackfoot River Mining Complex* (NRDP 2011) identified additional data needs that would be required to support preliminary and final designs. Among the recommendations was to identify and characterize reference reaches (i.e. analogs) to support the development of channel design criteria. In cooperation with NRDP and MFWP, reference reach investigations were completed in August 2012 on four main tributaries to the Blackfoot River near Lincoln, Montana, including Anaconda Creek, Arrastra Creek, Copper Creek, and Snowbank Creek (Figure 2-4). These reaches were selected because they are representative of the potential geomorphic and aquatic habitat conditions for stream reaches in the UBMC project area. The following sections describe the methods and results of the investigations.

2.2.1 Methods

Geomorphic channel data were collected with a Trimble 3303DR Total Station and Trimble 4 Model Global Positioning System (GPS) using a two-person survey crew. Total station survey data was processed and analyzed in RIVERMorph© version 4.2 (RIVERMorph LLC, 2005). Data collection parameters and methods are summarized in Table 2-5.

Table 2-5. Data collection parameters and methods.

Parameter	Method
Channel cross-section	Harrelson et al. 1994
Longitudinal channel profile	Harrelson et al. 1994
Planform geometry	Langbein and Leopold 1966
Substrate characterization	Wolman 1954
Riffle Stability Index	Kappeser, 1992
Aquatic habitat characterization	Overton et al. 1997
Channel classification	Rosgen 1996

The data sets include the actual measured morphologic values and dimensionless ratios that were derived by dividing the dimension, pattern, and profile variables by the bankfull value of the same feature. This approach allows the morphologic values to be extrapolated and used for channel design and floodplain design purposes.

Sections 2.2.2 through 2.2.5 provide descriptions of the reference reaches. Channel cross-section dimensionless ratios are summarized in Table 2-6. A complete data summary report is included in Appendix B.

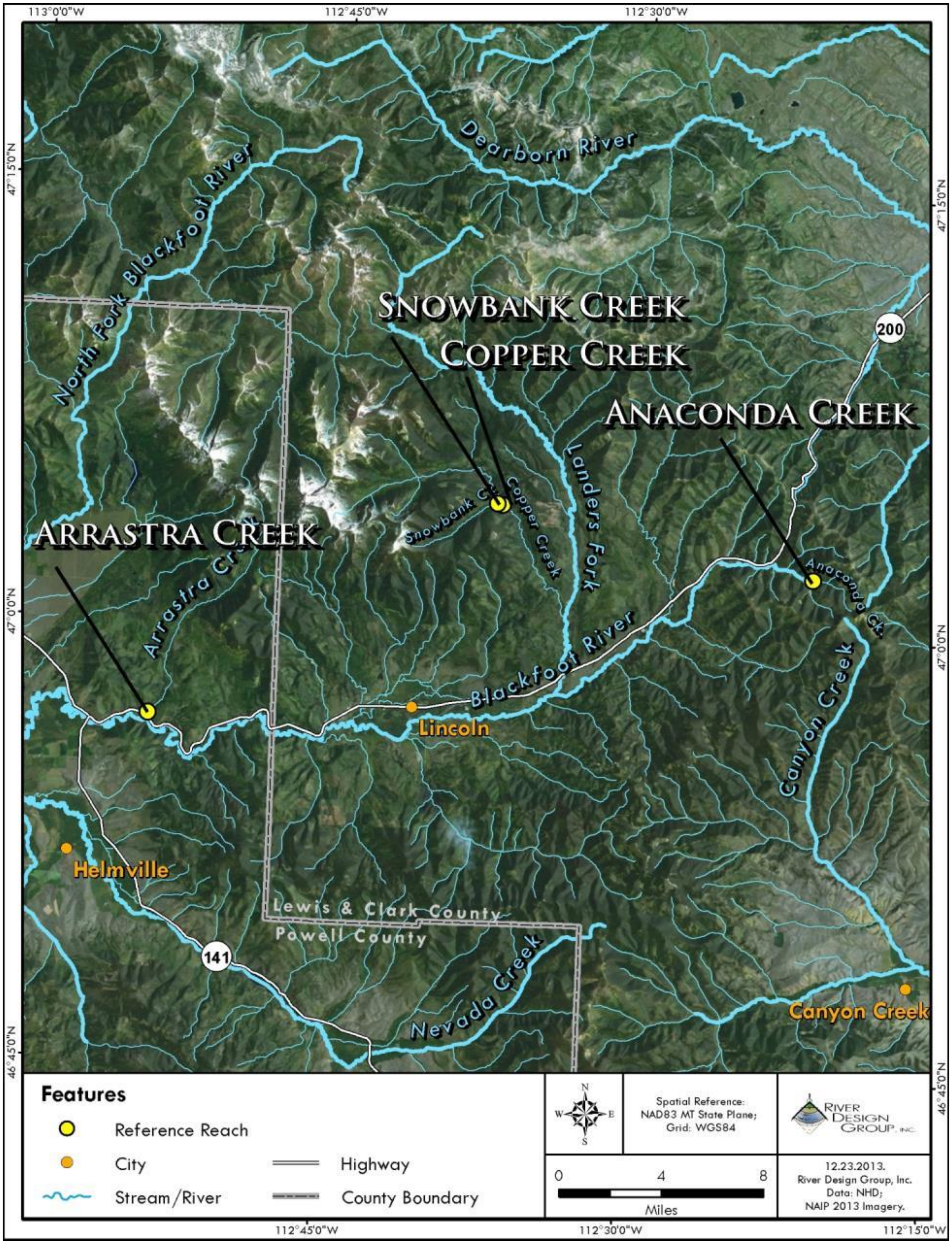


Figure 2-4. Upper Blackfoot River reference reach locations.

Table 2-6. Cross-section dimensionless ratios for UBMC reference reaches.

Metric	Reference Reach			
	Anaconda Creek	**Snowbank Creek**	**Arrastra Creek**	**Copper Creek**
Stream Type	B3 / B4	C4b	C4	C3 / C4
Average Slope (%)	3.3	2.3	1.3	0.8
Wfpa / Wbkf	1.81	6.86	6.74	2.66
Riffle Area / Abkf	1.00	1.00	1.00	1.00
Max Riffle Depth / Dbkf	1.28	1.62	1.44	1.28
Mean Riffle Depth / Dbkf	1.00	1.00	1.00	1.00
Riffle Width / Wbkf	1.00	1.00	1.00	1.00
Entrenchment Ratio/ER	1.00	6.84	6.7	2.66
Pool Area / Abkf	1.62	1.38	1.49	0.89
Max Pool Depth / Dbkf	2.47	2.35	2.38	2.19
Mean Pool Depth / Dbkf	1.46	1.34	1.04	1.20
Pool Width / Wbkf	1.15	1.10	1.46	1.13
Pool-Pool Spacing / Wbkf	4.10	3.80	4.10	5.20
Run Area / Abkf	0.91	1.16	0.98	0.99
Max Run Depth / Dbkf	1.56	1.94	1.68	2.02
Mean Run Depth / Dbkf	0.90	0.98	1.02	0.92
Run Width / Wbkf	1.01	1.20	0.96	1.24
Glide Area / Abkf	1.05	1.21	1.04	0.89
Max Glide Depth / Dbkf	1.67	1.94	1.51	1.54
Mean Glide Depth /Dbkf	0.92	1.25	0.88	0.99
Glide Width / Wbkf	1.17	0.97	1.18	1.00

[1]Wfpa = width of floodprone area; [2]Abkf = bankfull cross-sectional area; [3]Dbkf = bankfull mean depth; [4]Wbkf = bankfull channel width

2.2.2 Anaconda Creek: B3 / B4 Stream Type

Anaconda Creek is a tributary to Lower Beartrap Creek in Reach 3 of the project area (Figure 2-4). Anaconda Creek occurs in Valley Type II, characterized by valley floor slopes less than 4%, and soils derived from older residual soils, alluvium and colluvium. The channel is moderately entrenched with a narrow floodplain, and is bracketed between forested terraces. The channel form is primarily single-thread, and exhibits characteristics of a cobble and gravel dominated B stream type (Rosgen 1996) with an average slope of 3.3%, an average width to depth ratio of 10.7, and an average entrenchment ratio of 1.8. Channel substrate is sub-angular and consists of approximately 3% sand (≤2mm), 51% gravel (2 mm - 64 mm), 45% cobble (64 mm - 256 mm), and 1% boulders (256 mm - 1024 mm). Pool frequency in Anaconda Creek averages 6.7 pools per 100 meters with an average spacing of 47 feet or every 4.1 bankfull channel widths. Maximum pool depths range from 1.9 feet to 3.4 feet. Approximately 18.3 pieces of large wood per 100 meters (single pieces and rootwads with stems) were observed in the Anaconda Creek reference reach.

Figure 2-5 includes photos of the Anaconda Creek reference reach.

Figure 2-5. The Anaconda Creek reference reach located upstream of the confluence with Lower Beartrap Creek.

Channel cross-section dimensionless ratios for riffle, run, pool and glide habitat units are summarized in Table 2-6. Channel widths range from an average of 11.4 feet for riffle habitat units to 13.3 feet for glide habitat units. Mean depths range from 1.0 foot for run and glide habitat units to 1.6 feet for pool habitat units. Maximum pool depths range from 2.0 feet to 3.2 feet. As summarized in Section 2.1.2, bankfull discharge was estimated to be 55 cubic feet per second (cfs) with an average velocity of 4.5 feet per second (fps).

2.2.3 Snowbank Creek: C4b Stream Type

Snowbank Creek is a tributary to Copper Creek and is located approximately eight miles north and east of Lincoln, Montana (Figure 2-4). The reference reach is formed in a relatively narrow, terraced valley characterized by down-valley gradients of less than 4% and soils derived from alluvium and colluvium. The channel form is primarily single-thread and is classified as a C4b stream type with an average slope of 2.3%, an average width to depth ratio of 12.1, and an average entrenchment ratio of 6.6. Channel substrate is sub-rounded and consists of approximately 7% sand (≤2 mm), 57% gravel (2 mm - 64 mm), and 36% cobble (64 mm - 256 mm). Channel bedforms consist of riffle-pool and step-pool sequences. Pool frequency in Snowbank Creek averages 5.1 pools per 100 meters with an average spacing of 58 feet or every 3.8 bankfull channel widths. Maximum pool depths range from 2.4 feet to 3.5 feet. Approximately 30.7 pieces of large wood per 100 meters (single pieces and rootwads with stems) were observed in the Snowbank Creek reference reach. Riparian and floodplain areas in the Snowbank Creek reference reach have been affected by stand-replacing wildfires; existing dead, standing trees provide a source of coarse wood to the channel.

Figure 2-6 includes photos of the Snowbank Creek reference reach.

Figure 2-6. Typical geomorphic and aquatic habitat conditions in the Snowbank Creek reference reach.

Channel cross-section dimensionless ratios for riffle, run, pool and glide habitat units are summarized in Table 2-6. Channel widths range from an average of 14.7 feet for glide habitat units to 18.2 feet for run habitat units. Mean depths range from 1.2 feet to 1.7 feet for run and pool habitat units, respectively. Maximum pool depths range from 2.4 feet to 3.5 feet. Bankfull discharge is estimated to be 136 cfs with an average velocity of 5.8 fps.

2.2.4 Arrastra Creek: C4 Stream Type

Arrastra Creek is a tributary to the Blackfoot River located approximately 10 miles west of Lincoln, Montana (Figure 2-4). Arrastra Creek occurs in Valley Type V characterized by glacial moraines, terraces and floodplains. The channel form is primarily single-thread with secondary side channels developed on active floodplain surfaces. The reach is classified as a slightly entrenched, meandering, riffle-pool, gravel dominated C4 stream type with an average slope of 1.3%, an average width to depth ratio of 15.9, and an average entrenchment ratio of 6.7. Channel substrate is sub-rounded and consists of 1% sand (≤2 mm), 64% gravel (2 mm - 64 mm), and 35% cobble (64 mm - 256 mm). Pool frequency in Arrastra Creek averages 3.6 pools per 100 meters with an average spacing of 103 feet or every 4.1 bankfull channel widths. Maximum pool depths range from 3.6 feet to 3.9 feet. Approximately 14.8 pieces of large wood per 100 meters (single pieces and rootwads with stems) were observed in the Arrastra Creek reference reach.

Channel cross-section dimensionless ratios for riffle, run, pool and glide habitat units are summarized in Table 2-6. Channel widths range from an average of 24.0 feet for run habitat units to 36.6 feet for pool habitat units. Mean depths range from 1.4 feet to 1.6 feet for riffle and pool habitat units, respectively. Maximum pool depths range from 3.6 feet to 3.9 feet. Bankfull discharge is estimated to be 225 cfs with an average velocity of 5.5 fps.

Figure 2-7 includes photos of the Arrastra Creek reference reach.

Figure 2-7. Typical geomorphic and aquatic habitat conditions in the Arrastra Creek reference reach.

As shown in Figure 2-7, large wood loading influences the development and distribution of complex aquatic habitat units in Arrastra Creek.

2.2.5 Copper Creek: C3 / C4 Stream Type

The Copper Creek reference reach is an alluvial reach and primary tributary to the Blackfoot River located approximately eight miles north and east of Lincoln, Montana (Figure 2-4). Similar to Snowbank Creek, Copper Creek exhibits a meandering channel pattern and is characterized by a dominant channel with secondary side channels developed on active floodplain and low terrace surfaces. The reach is classified as a low gradient, cobble and gravel dominated C stream type with riffle-pool bedforms. The average reach slope is 0.8%, the width to depth ratio averages 23, and the floodplain is well developed with an average width of 98 feet (entrenchment ratio of 2.6). The morphology is controlled by the presence of floodplain and low terrace surfaces that moderate channel bend migration rates.

Channel substrate is sub-rounded and consists of 9% sand (≤2 mm), 40% gravel (2 mm - 64 mm), 46% cobble (64 mm - 256 mm), and 6% boulders (256 mm - 1024 mm). Pool frequency in Copper Creek averages 2.6 pools per 100 meters with an average spacing of 193 feet or every 5.2 bankfull channel widths. Maximum pool depths range from 2.9 feet to 3.8 feet. Approximately 33.5 pieces of large wood per 100 meters (single pieces and rootwads with stems) were observed in the Copper Creek reference reach. Of the inventoried reaches, Copper Creek demonstrated the highest distribution and volume of large wood. Bankfull discharge is 316 cfs with an average velocity of 4.1 fps.

Figure 2-8 includes photos of the Copper Creek reference reach.

Figure 2-8. Typical geomorphic and aquatic habitat conditions in the Copper Creek reference reach.

2.3 Hydraulics

This section describes the modeling effort used to evaluate the preliminary channel and floodplain design in terms of hydraulic performance, stability, and sediment transport continuity. The purpose for completing the initial modeling exercise was to evaluate hydraulic performance at both the reach and project-scales in order to refine the preliminary channel and floodplain design dimensions. The information presented in this section forms the basis for the geomorphic design criteria described in Section 3 of this report. Methods and results are described in the following sections.

2.3.1 Methods

The preliminary design channel (riffle template) and floodplain grading surfaces were merged with the existing LiDAR surface in AutoCAD Civil 3d to create a seamless digital terrain model of the channel and floodplain morphology in Reaches 2- 5. Reach 1 Mike Horse Creek and Reach 6 Lower Blackfoot River were excluded from the grading plan and modeling effort as remedial and restoration plans are still in the conceptual design phase. Hydraulic performances for channel and floodplain design geometries were simulated using HEC-RAS version 4.1.0 (USACE 2010), a one-dimensional gradually varied flow hydraulic model. Channel and floodplain dimensions and transitions were adjusted to refine hydraulic performance relative to a range of discharges from bankfull to the estimated 100-year flood. Design discharges were estimated using a combination of hydraulic and hydrologic analyses as described in Section 2.1 of this report. In addition to discrete flow values representing specific recurrence interval discharges, a continuous range of flows were modeled in order to analyze hydraulic performance at specific locations in the project area.

The Limerinos equation for relative roughness (Limerinos 1970) was used to estimate channel roughness values. Floodplain values were selected to be representative of post-restoration conditions that will include vegetative, coarse wood, and micro-topographic treatments. Channel bed material sizes were refined based on estimated mobile grain size using the average of three methods including Shields (1936), Leopold, et. al. (1964), and Rosgen (2006). Channel roughness values were recalculated using an iterative approach to ensure that the values were consistent with the predicted hydraulic depth at the estimated bankfull discharge. Floodplain roughness values were held constant for all model runs.

Data summary graphs were prepared to evaluate mean channel velocity, section averaged channel shear stress, estimated mobile particle size, and floodplain values for velocity and shear stress. These hydraulic parameters were evaluated for a range of discharge conditions and discrete recurrence intervals including bankfull discharge (Qbkf), Q10, Q25, Q50 and Q100 flood discharges. Appendix C includes figures illustrating the hydraulic modeling results.

2.3.2 Results

Hydraulic modeling results indicate a wide range of hydraulic and bed mobility conditions. Average energy gradients in the project area range from a maximum of 3.9% in Reach 2 Upper Beartrap Creek to 0.7% in Reach 5 Middle Blackfoot River. The decreasing energy gradient reflects the gradual transition from the steeper, more confined channel and valley morphology in Reaches 2-3, to the unconfined alluvial valleys in Reaches 4-6.

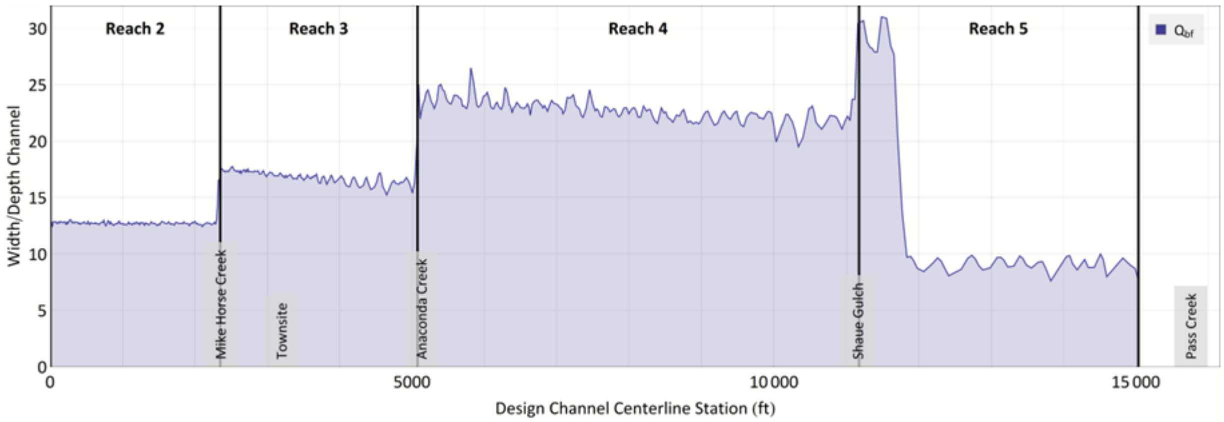


Figure 2-9. Longitudinal plot of channel width to depth ratio for Reaches 2-5 for flood recurrence interval flows.

Longitudinal plots of channel width to depth ratios, average channel velocities and average mobile particle sizes show the range of values for discrete recurrence intervals including bankfull discharge (Qbkf), Q10, Q25, Q50 and Q100 flood discharges. Significant changes in width to depth ratios for bankfull discharge are shown in Figure 2-9. These changes occur at the channel grading transition points which include the three major tributaries and the change in channel type in Reach 5. Width to depth ratios within Reaches 2-4 are relatively consistent with average values of 12.8 for Reach 2, 16.8 for Reach 3, and 22.8 for Reach 4. Width to depth ratios in Reach 5 decrease at the point where the C4 channel transitions to an E4 channel with average values 26.0 for Sub-reach 5A (C4 stream type) and 9.1 for Sub-reach 5B (E4 stream type).

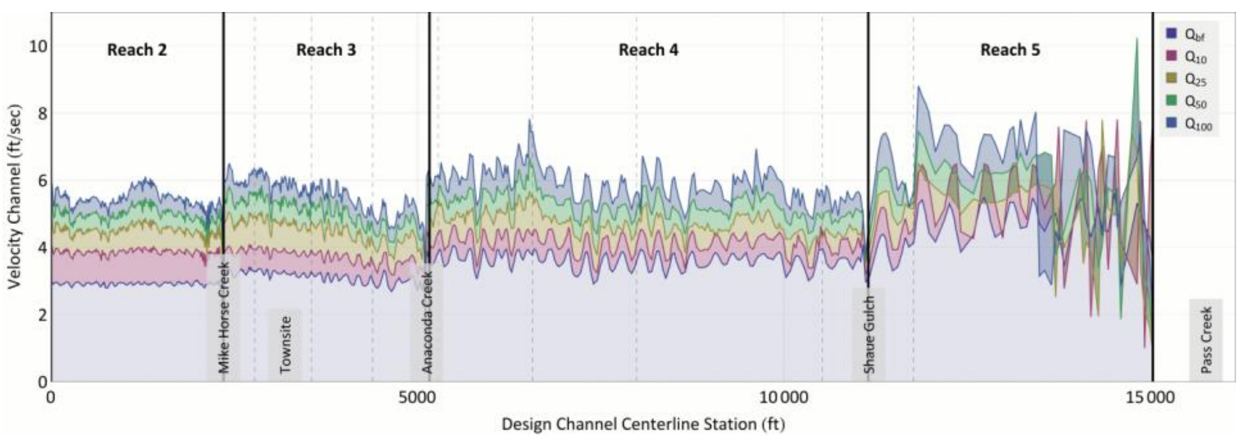


Figure 2-10. Longitudinal plot of modeled average channel velocities for Reaches 2-5 for flood recurrence interval flows.

The longitudinal plot of modeled average channel velocities for Reaches 2-5 shown in Figure 2-10 are relatively consistent for Reaches 2-4. The sinusoidal variability apparent in Reach 4 and Reach 5, especially at the higher recurrence intervals, is related to fluctuation in the local channel bed slope as the channel alternately meanders across and perpendicular to the valley slope. This variability will likely decrease when pools and runs are added to the design grading surface. Channel velocities in Reaches 2-4 are relatively consistent with average bankfull and Q100 values of 2.9 fps and 5.5 fps for Reach 2, 3.2 fps and 5.7 fps for Reach 3, and 3.6 fps and 5.9 fps for Reach 4. Channel velocities in Reach 5 increase with the addition of flow from Shaue (Shave) Gulch with average bankfull and Q100 values of 4.0 fps and 6.5 fps for the C4 stream type and 4.8 fps and 6.4 fps for the E4 stream type. The spikes in velocity near the downstream end of Reach 5 are related to floodplain convexity, the perched channel, and variability in the floodplain as it expands and contracts.

The sinusoidal variability evident in the longitudinal plot of modeled channel shear stress and average mobile particle sizes for Reaches 2-5 shown in Figure 2-11 is also related to fluctuation in the local channel bed slope as the channel alternately meanders across and perpendicular to the valley slope. Channel dimensions were adjusted so that channel shear stress and average mobile particle sizes progressively decrease in the downstream direction. This will help to ensure that continuity of sediment transport is maintained through the project. Average channel shear stress values for bankfull flow progressively decrease from 1.9 pound (force) per square foot (lbf/ft^2) to 0.8 lbf/ft^2 in Reaches 2-5. The average mobile particle size class for bankfull flow progressively decreases from small boulder (SB) in Reach 2 to large cobble (LC) in Reach 5. Average channel shear stress values for Q100 progressively decrease from 4.9 lbf/ft^2 to 1.2 lbf/ft^2 in Reaches 2-5. Corresponding average mobile particle size classes decrease from large boulders (LB) to large cobbles (LC) in Reaches 2-4. Mobile particle size classes for Q100 flow in the C4 sub reach range from small cobbles (SC) to small boulders (SB) and from medium gravel (MG) to small boulders (SB) in the E4 sub reach.

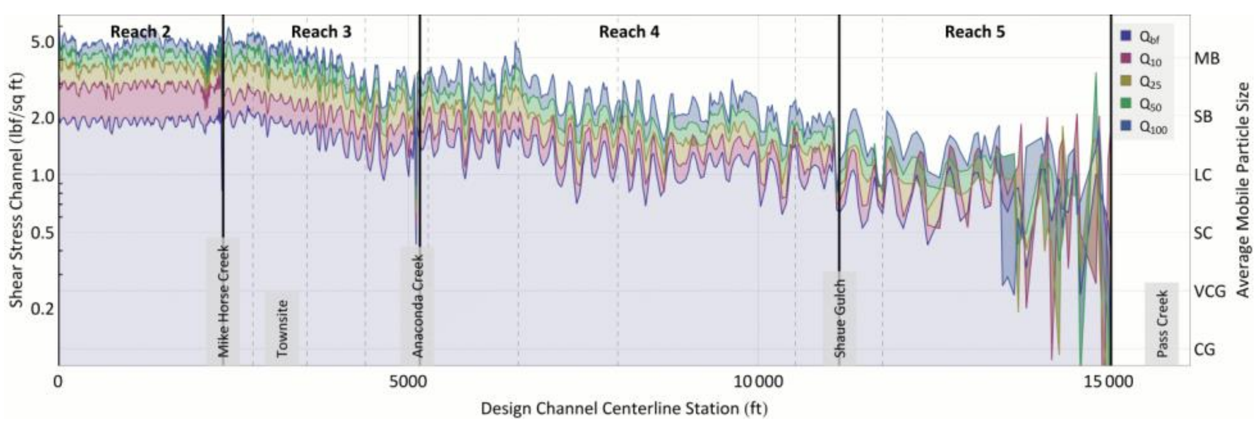


Figure 2-11. Longitudinal plot of modeled channel shear stress and average mobile particle sizes for Reaches 2-5 for flood recurrence interval flows.

Rating tables for representative cross sections in Reaches 2-5 showing average channel shear stress and mobile particle sizes over a range of flood recurrence intervals from Qbkf to Q100 are presented below, by reach. Also shown for each reach is a rating table of average overbank velocity and shear stress over the same range of flood recurrence intervals.

Reach 2 Upper Beartrap Creek

The representative channel rating table for Reach 2 is shown in Figure 2-12 for a B2/3a channel type at 4.3% slope. Reach average channel shear stress increases from the 1.9 lbf/ft^2 to 4.9 lbf/ft^2 for the bankfull to Q100 flows of 25 cfs to 274 cfs. The corresponding reach average mobile particle size ranges from 240 mm to 611 mm.

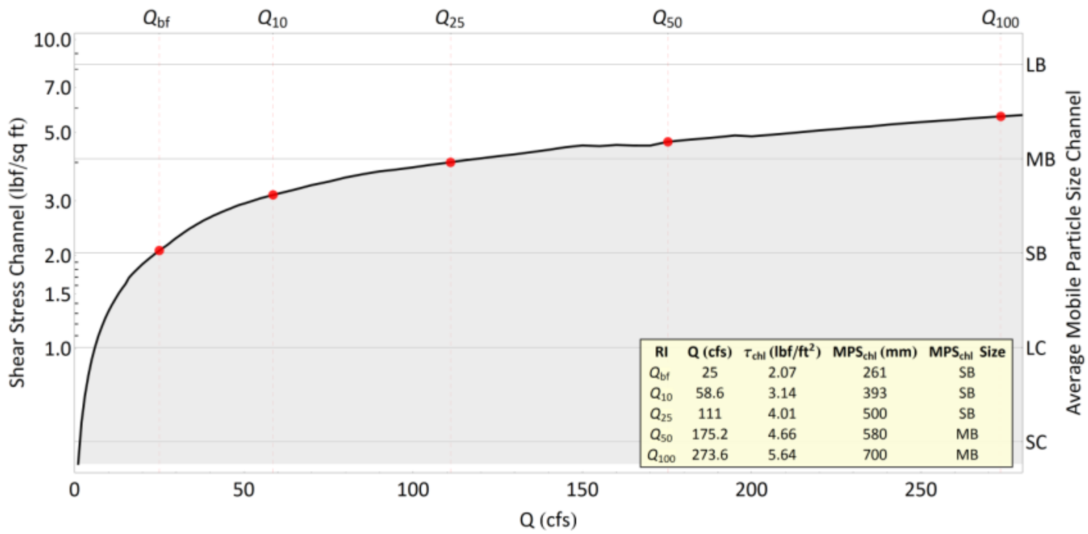


Figure 2-12. Modeled average channel shear stress and mobile particle sizes for flood recurrence interval flows.

The representative overbank rating table for Reach 2 is shown in Figure 2-13. Reach average overbank velocities range from 1.0 fps to 2.5 fps for the estimated Q10 to Q100 flows of 59 cfs to 274 cfs with an overall maximum of 5.0 fps. Corresponding reach average overbank shear stress values increase from 0.5 lbf/ft^2 to 1.7 lbf/ft^2 with an overall maximum of 4.8 lbf/ft^2.

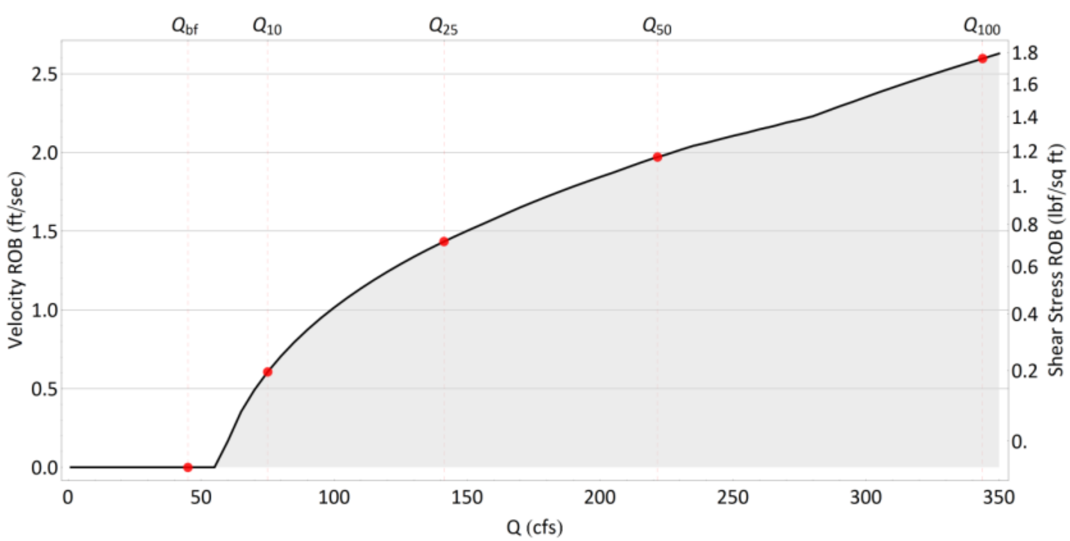


Figure 2-13. Modeled average overbank velocity and shear stress for flood recurrence interval flows.

Reach 3 Lower Beartrap Creek

The representative channel rating table for Reach 3 is shown in Figure 2-14 for a B3 channel type at 3.9% slope. Reach average channel shear stress increases from the 1.7 lbf/ft^2 to 4.2 lbf/ft^2 for the bankfull to Q100 flows of 45 cfs to 344 cfs. The corresponding reach average mobile particle size ranges from 216 mm to 524 mm.

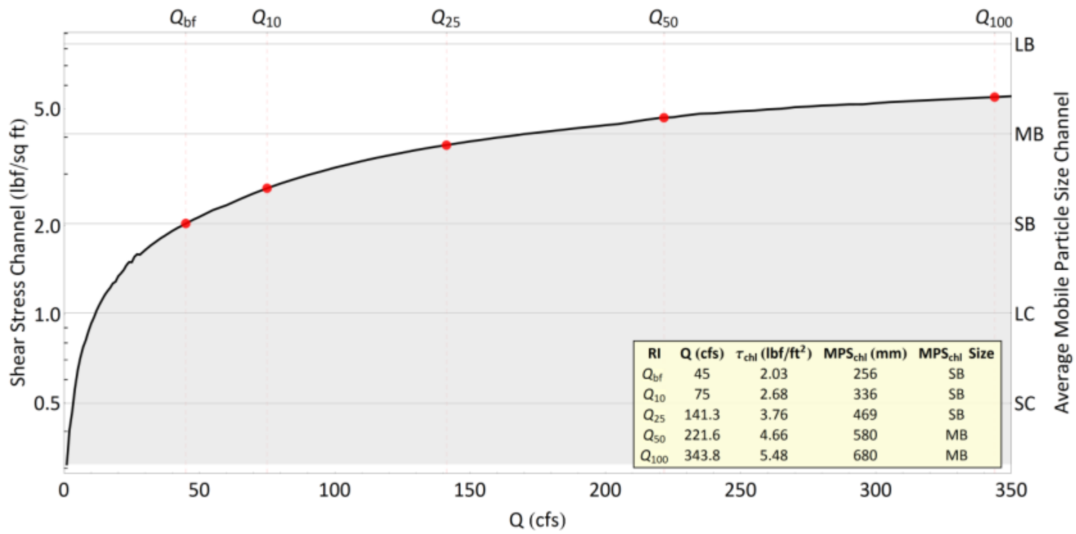


Figure 2-14. Modeled average channel shear stress and mobile particle sizes for flood recurrence interval flows.

The representative overbank rating table for Reach 3 is shown in Figure 2-15. Reach average overbank velocities range from 0.6 fps to 2.2 fps for the estimated Q10 to Q100 flows of 75 cfs to 344 cfs with an overall maximum of 4.8 fps. Corresponding reach average overbank shear stress values increase from 0.2 lbf/ft^2 to 1.3 lbf/ft^2 with an overall maximum of 4.5 lbf/ft^2.

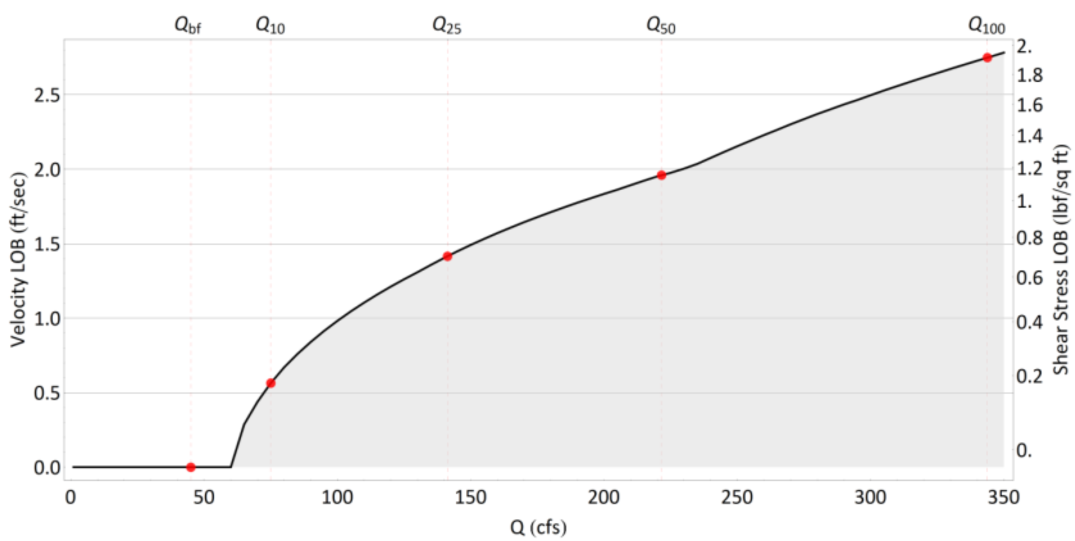
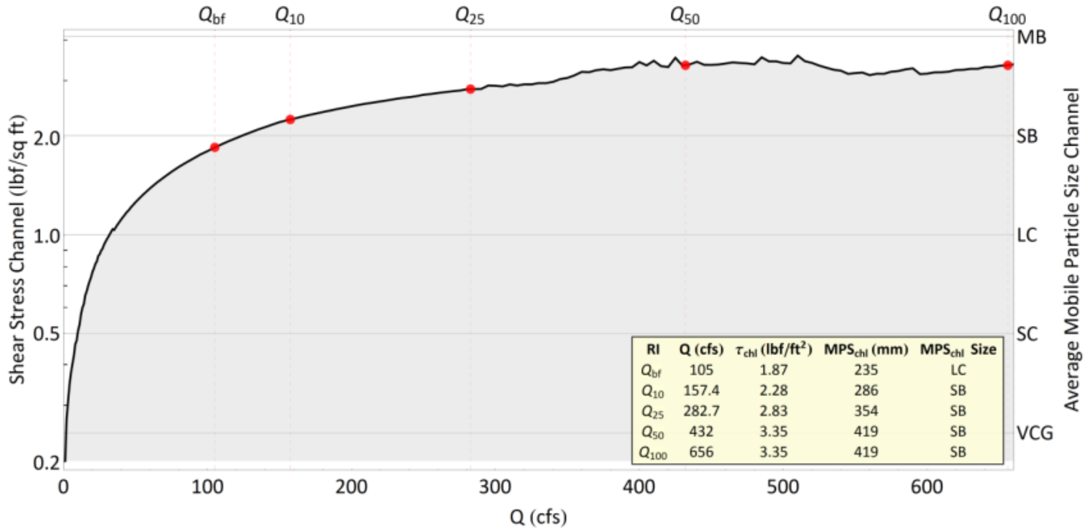


Figure 2-15. Modeled average overbank velocity and shear stress for flood recurrence interval flows.

Reach 4 Upper Blackfoot River

The representative channel rating table for Reach 4 is shown in Figure 2-16 for a B3c channel type at 2.7% slope. Reach average channel shear stress increases from 1.3 lbf/ft^2 to 2.7 lbf/ft^2 for the bankfull to Q100 flows of 105 cfs to 656 cfs. The corresponding reach average mobile particle size ranges from 161 mm to 337 mm.



RI	Q (cfs)	τ_{chl} (lbf/ft^2)	MPS_{chl} (mm)	MPS_{chl} Size
Q_{bf}	105	1.87	235	LC
Q_{10}	157.4	2.28	286	SB
Q_{25}	282.7	2.83	354	SB
Q_{50}	432	3.35	419	SB
Q_{100}	656	3.35	419	SB

Figure 2-16. Modeled average channel shear stress and mobile particle sizes for flood recurrence interval flows.

The representative overbank rating table for Reach 4 is shown in Figure 2-17. Reach average overbank velocities range from 0.4 fps to 2.0 fps for the estimated Q10 to Q100 flows of 157 cfs to 656 cfs with an overall maximum of 5.2 fps. Corresponding reach average overbank shear stress values increase from 0.1 lbf/ft^2 to 0.9 lbf/ft^2 with an overall maximum of 4.4 lbf/ft^2.

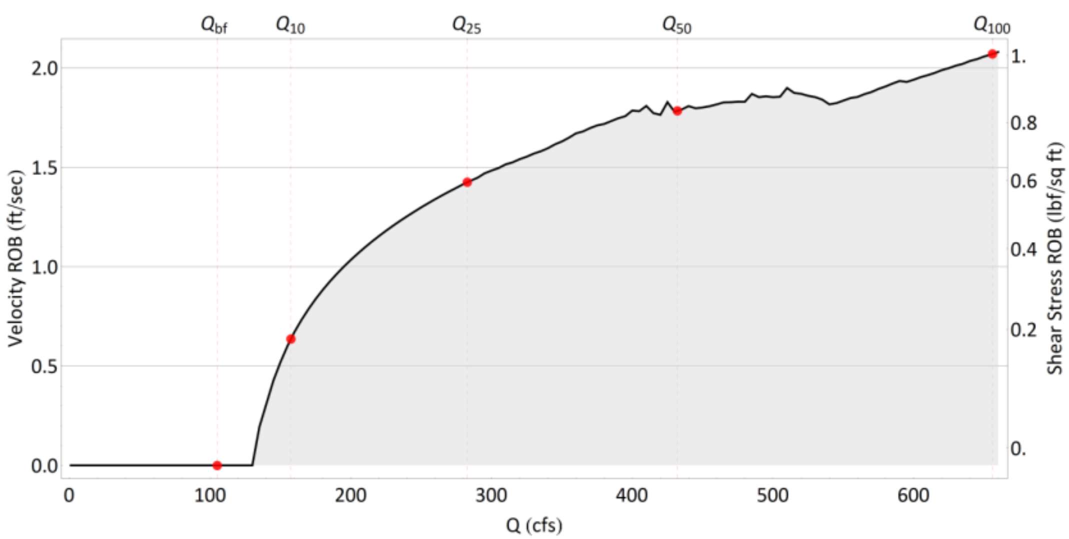
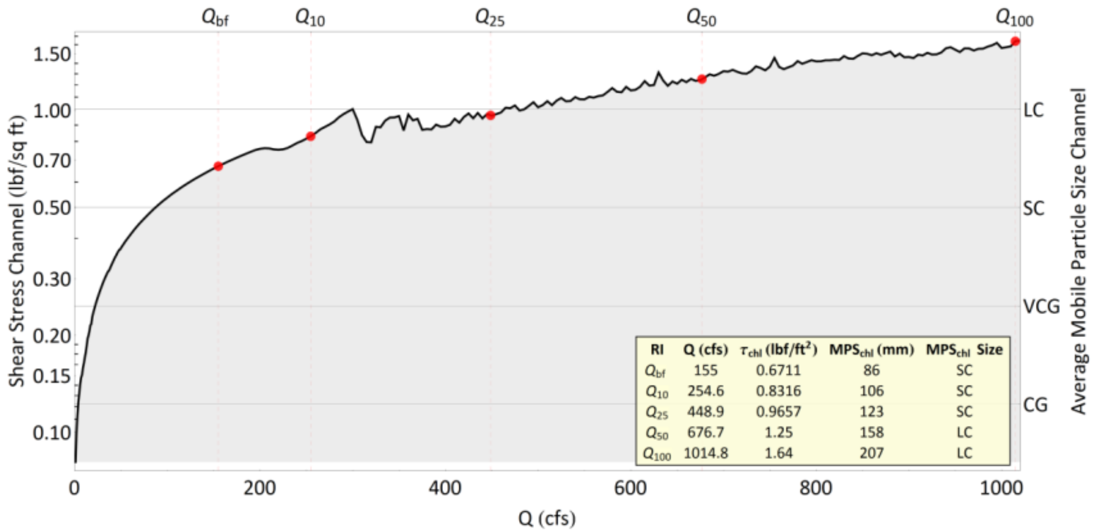


Figure 2-17. Modeled average overbank velocity and shear stress for flood recurrence interval flows.

Reach 5 Middle Blackfoot River – C3 and C4 Stream Type

The representative channel rating table is shown in Figure 2-18 for a C4 stream type at 0.7% slope. Reach average channel shear stress increases from the 0.8 lbf/ft^2 to 1.6 lbf/ft^2 for the bankfull to Q100 flows of 155 cfs to 1,015 cfs. The corresponding reach average mobile particle size ranges from 102 mm to 202 mm.



RI	Q (cfs)	τ_{chl} (lbf/ft^2)	MPS_{chl} (mm)	MPS_{chl} Size
Q_{bf}	155	0.6711	86	SC
Q_{10}	254.6	0.8316	106	SC
Q_{25}	448.9	0.9657	123	SC
Q_{50}	676.7	1.25	158	LC
Q_{100}	1014.8	1.64	207	LC

Figure 2-18. Modeled average channel shear stress and mobile particle sizes for flood recurrence interval flows.

The representative overbank rating table for a C4 stream type is shown in Figure 2-19. Reach average overbank velocities range from 0.3 fps to 1.7 fps for the estimated Q10 to Q100 flows of 255 cfs to 1,015cfs with an overall maximum of 3.6 fps. Corresponding reach average overbank shear stress values increase from 0.1 lbf/ft^2 to 0.6 lbf/ft^2 with an overall maximum of 2.1 lbf/ft^2.

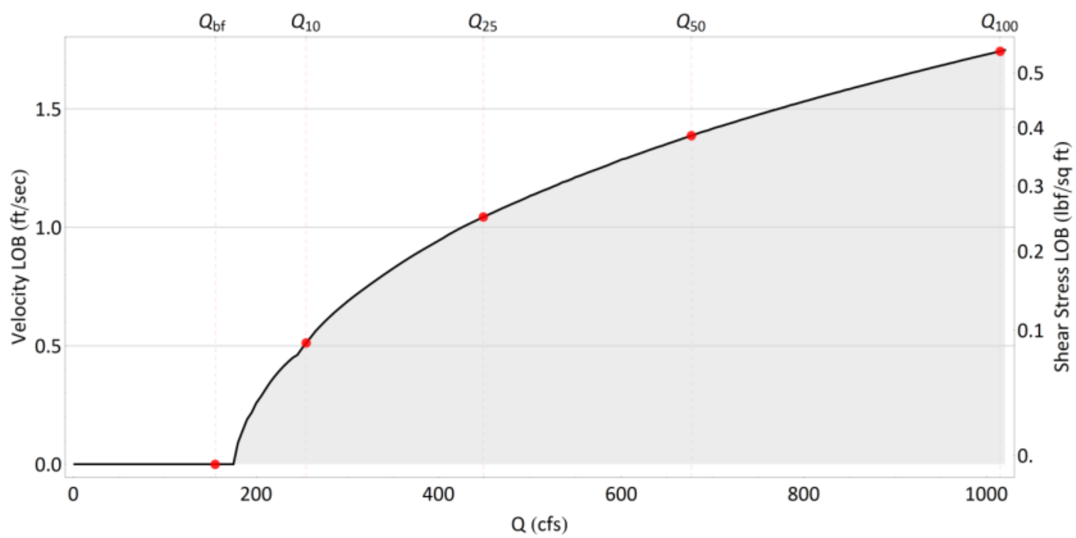
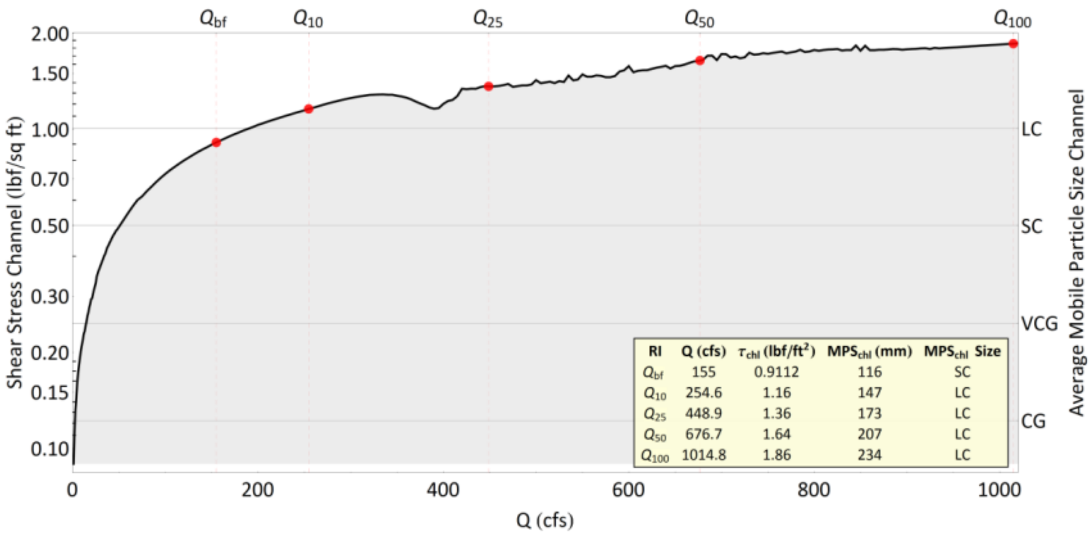


Figure 2-19. Modeled average overbank velocity and shear stress for flood recurrence interval flows.

Reach 5 Middle Blackfoot River – E4 Stream Type

The representative channel rating table for an E4 stream type at 0.5% slope is shown in Figure 2-20. Reach average channel shear stress increases from the 0.8 lbf/ft^2 to 1.2 lbf/ft^2 for the bankfull to Q100 flows of 155 cfs to 1,015 cfs. The corresponding reach average mobile particle size ranges from 100 mm to 156 mm.



RI	Q (cfs)	τ_{chl} (lbf/ft^2)	MPS_{chl} (mm)	MPS_{chl} Size
Q_{bf}	155	0.9112	116	SC
Q_{10}	254.6	1.16	147	LC
Q_{25}	448.9	1.36	173	LC
Q_{50}	676.7	1.64	207	LC
Q_{100}	1014.8	1.86	234	LC

Figure 2-20. Modeled average channel shear stress and mobile particle sizes for flood recurrence interval flows.

The representative overbank rating table for the E4 stream type is shown in Figure 2-21. Reach average overbank velocities range from 0.3 fps to 1.3 fps for the estimated Q10 to Q100 flows of 255 cfs to 1,015cfs with an overall maximum of 3.5 fps. Corresponding reach average overbank shear stress values increase from 0.04 lbf/ft^2 to 0.4 lbf/ft^2 with an overall maximum of 1.7 lbf/ft^2.

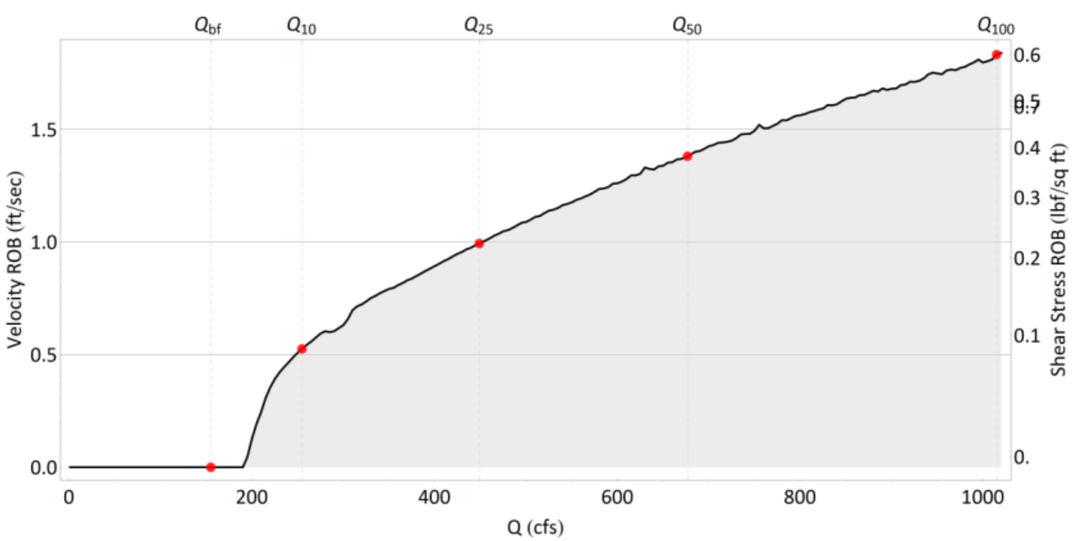


Figure 2-21. Modeled average overbank velocity and shear stress for flood recurrence interval flows.

2.4 Tie-In Analysis

This section summarizes the preliminary channel and floodplain design tie-in analysis for primary tributaries in the project area including Mike Horse Creek, Beartrap Creek, Anaconda Creek, and Shaue (Shave) Gulch. The purpose for identifying tie-in locations and elevations is to ensure the design channel alignments and longitudinal profile elevations match existing channel and floodplain surface elevations at the specified tie-in locations outside of the grading plan extents. A map noting the tie-in locations is provided in Figure 2-22.

2.4.1 Methods

Channel and floodplain features were surveyed in August 2013 with a Trimble 3303DR Total Station and Trimble 4 Model GPS using a survey crew. Investigations were completed at four locations in the project area, including:

- Reach 1 Mike Horse Creek at the existing coffer dam diversion (sub-reach 1A).
- Reach 2 Upper Beartrap Creek above the existing diversion dam and Kornec Creek.
- Anaconda Creek.
- Shaue (Shave) Gulch.

Four additional tie-in locations were evaluated during the design process including:

- Confluence of Reach 1 Mike Horse Creek and Reach 2 Upper Beartrap Creek.
- Confluence of Reach 3 Lower Beartrap Creek and Anaconda Creek.
- Confluence of Reach 4 Upper Blackfoot River and Shaue (Shave) Gulch.
- Transition from Reach 5 Middle Blackfoot River to Reach 6 Lower Blackfoot River.

Channel thalweg and floodplain elevations were calculated by applying a quadratic asymptotic curve to the tie-in elevations and subtracting the mean depth of the design channel cross-section from the floodplain elevation to determine channel thalweg elevations.

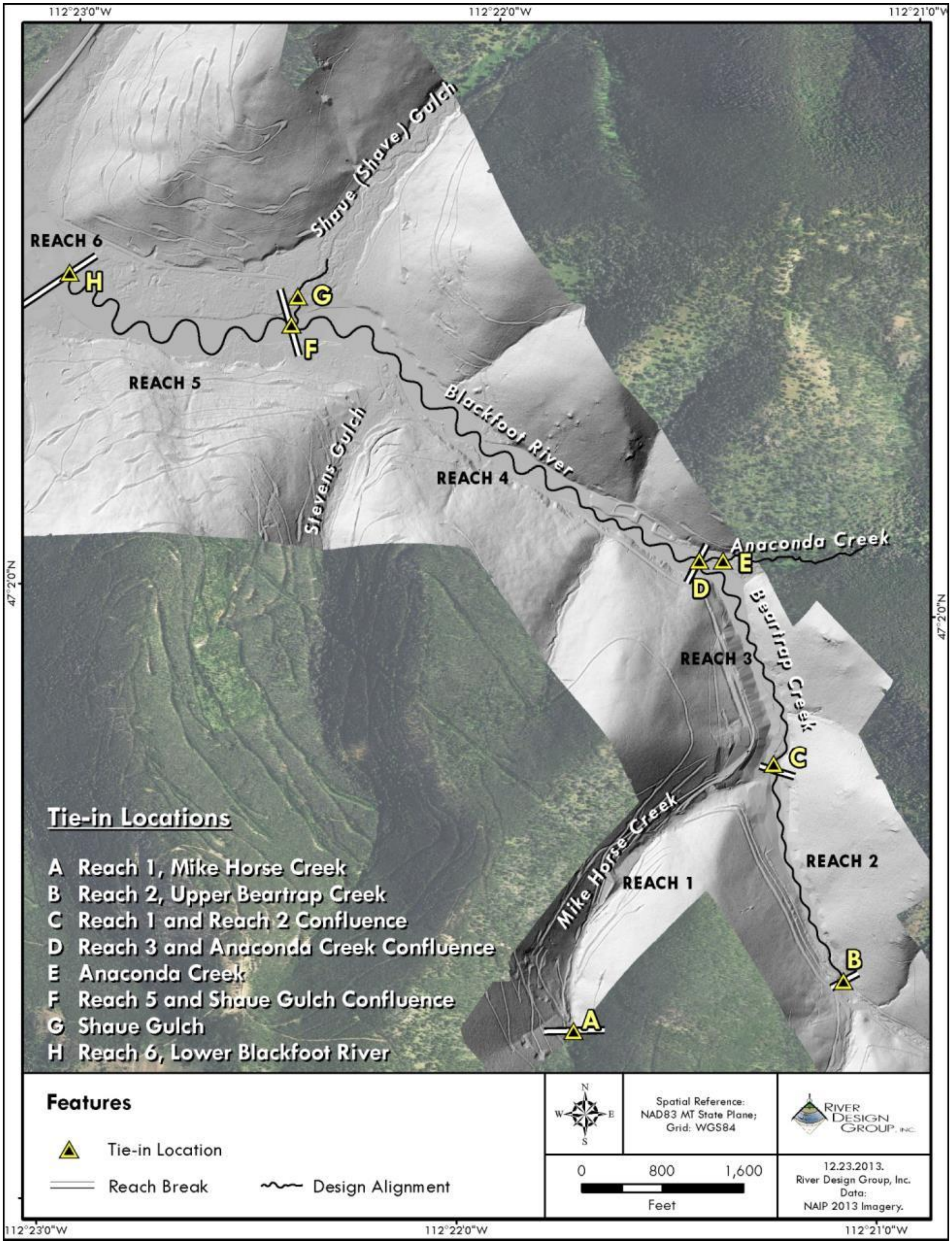


Figure 2-22. Channel and floodplain design tie-in locations.

2.4.2 Results

Results of the tie-in analysis are summarized in Table 2-7. Site photos of the primary tributary tie-in locations are provided in Figures 2-23 and 2-24.

Table 2-7. Summary of tie-in elevations.

Reach	Design Channel Centerline Station	Design Thalweg Elevation	Floodplain Elevation	Draft Elevation[1]
Reach 1 Mike Horse Creek	0+00	N/A	5811.0	5808.7
Reach 2 Upper Beartrap Creek	0+00	5499.9	5501.3	N/A
Reach 1 and Reach 2 confluence	24+00	5407.5	5409.0	5412.5
Reach 3 and Anaconda Creek confluence	50+75	5329.1	5330.5	5327.1
Anaconda Creek	15+42	5334.2	5335.5	N/A
Reach 5 and Shaue (Shave) Gulch confluence	111+75	5223.2	5225.0	5222.9
Shaue (Shave) Gulch	5+28	5232.2	5233.4	N/A
Reach 6 Lower Blackfoot River	150+40	5193.54	5196.6	5194.3

Figure 2-23. Longitudinal channel profile tie-in locations for Mike Horse Creek (left) and Upper Beartrap Creek (right).

Figure 2-24. Longitudinal channel profile tie-in locations for Anaconda Creek (left) and Shaue (Shave) Gulch (right).

2.5 Vegetation Analysis

Existing vegetation communities were delineated during the 2012 and 2013 growing seasons in order to describe plant communities and identify wetland locations. This information is useful as a reference for developing planting and seeding plans to guide restoration actions, and to identify areas that should be preserved during excavation associated with remediation. Unique vegetation communities were identified in the field when obvious differences were visible with respect to several criteria that could potentially be linked to presence of contamination, or used for riparian and floodplain restoration design. These criteria included upland vs. hydrophytic vegetation, wetland status, soil saturation, geomorphic position, life form (tree, shrub or herbaceous), visible tailings deposits, signs of land use and disturbance, or presence and amount of bare ground. Appendix D includes figures showing vegetation mapping for the riparian corridor within the UBMC project area. Descriptions of the vegetation communities identified in the field are provided in Section 2.5.2.

2.5.1 Methods

During field visits, the extents of distinct vegetation communities were delineated over aerial photographs, and representative boundaries were mapped using a resource grade GPS unit. Information about plant species, topography, hydrology, and tailings presence was collected at representative locations within each vegetation community. A GPS point was recorded and photographs were taken at each location where data were collected. Based on this information, descriptive plant community categories were developed according to dominant plant species composition and life form, geomorphic position, visible tailings, level of disturbance, and presence of bare ground. A total of 21 existing vegetation communities and four non-vegetated categories (open water, main channel, gully and berm) were described for the UBMC Reaches 1 through 6. Plot data are included in Appendix D.

2.5.2 Existing Vegetation Communities

Upland Herbaceous

This vegetation community consists of upland areas dominated by herbaceous vegetation and often occurs as patches within other vegetation communities. Some of these areas appear to include tailings. Dominant vegetation includes redtop (*Agrostis gigantea*) with a few interspersed tree seedlings. Figure 2-1 (left photo) shows the upland herbaceous community type within a forested matrix.

Disturbed Upland

This vegetation community occurs on high surfaces where the rooting zone is above the water table, typically away from stream channels. These areas are disturbed but not obviously contaminated. Examples of observed disturbance include campgrounds, two track roads, and areas with cleared trees and other vegetation (Figure 2-25; right photo). Dominant vegetation includes lodgepole pine (*Pinus contorta*) in the overstory and timothy grass (*Phleum pratense*), yarrow (*Achillea millefolium*), kinnikinnik (*Arctostaphylos uva-ursi*), and spotted knapweed (*Centaurea stoebe*) in the understory. Soils are mostly disturbed and consist of a mixture of loam and cobble.

Figure 2-25. Upland Herbaceous (left) and Disturbed Upland (right) vegetation communities.

Contaminated Berm

This vegetation community is represented by one polygon (Appendix D), and the area appears to be a tailings pile that was intentionally constructed.

Herbaceous Berm

This vegetation community includes one polygon (Appendix D) where there is a berm within a forested upland area that only has herbaceous vegetation growing on it. This area may be a tailings pile.

Alluvial Bar

These areas are adjacent to the channel in both reaches where alluvial material has recently been deposited (Figure 2-26). These features are similar to the vegetated bar vegetation community but are more sparsely vegetated with dominant vegetation including field horsetail (*Equisetum arvense*), bebb willow (*Salix bebbiana*), Sitka alder (*Alnus viridis*), and bluejoint reedgrass (*Calamagrostis canadensis*).

Figure 2-26. Alluvial Bars occupy fringes along the channel margins.

Vegetated Bar

These areas are similar to the alluvial bar vegetation community, except that more vegetation has become established (Figure 2-27; left photo). Dominant vegetation includes lodgepole pine, field horsetail, Sitka alder, narrowleaf willow (*Salix exigua*), and Ute lady's tresses (*Spiranthes diluvialis*).

Forested Emergent Wetland

This vegetation community includes wetlands with at least 30% tree canopy cover and is located on the fringe of the large wetland complex. These areas are either paludified forest attributed to higher groundwater levels caused by beaver activity and/or slope wetlands sustained by groundwater discharge from adjacent hillslopes. Dominant vegetation includes lodgepole pine, Northwest Territory sedge (*Carex utriculata)*, water sedge (*Carex aquatilis)*, bluejoint reedgrass, subalpine fir (*Abies lasiocarpa*), and *Sphagnum* moss (Figure 2-27; right photo). Soils consist of loam down to 16 inches. Forested wetlands are uncommon in Montana and are therefore a unique wetland community type.

Figure 2-27. Vegetated Bar with *Equisetum* spp. just below the treatment facility (left), and Forested Emergent Wetland (right).

Forested Shrub Wetland

This vegetation community includes wetlands with at least 30% canopy cover by trees including lodgepole pine and subalpine fir (Figure 2-28). The understory is primarily dominated by shrub species including Drummond's willow (*Salix drummondiana)*, bebb willow, and Booth's willow (*Salix boothii)*. Dominant herbaceous vegetation is typically Northwest Territory sedge. Soils vary between loam and mucky mineral topsoil underlain by gravel subsoil. Forested wetlands are uncommon in Montana and are therefore a unique wetland community type.

Figure 2-28. Forested Shrub Wetland. Downstream area with an intact vegetation community (left), and an area which may once have looked similar to the photograph on the left, but appears to have been partially buried by tailings (right).

Forested with Upland Herbaceous

This vegetation community includes areas with 30% or more tree canopy cover with an understory dominated by upland herbaceous vegetation (Figure 2-29; left photo). Dominant tree species include lodgepole pine, subalpine fir, and Engelmann spruce (*Picea engelmannii*). Dominant vegetation in the herbaceous layer includes common cowparsnip (*Heracleum maximum)*, bluejoint reedgrass, arrowleaf groundsel (*Senecio triangularis)*, and kinnikinnik. Soils within the vegetation plot consisted of a loam topsoil down to 24 inches. Within this vegetation community it is common to see small pockets of wetland.

Forested Bare Ground

This vegetation community includes areas with at least 30% cover of trees and 10% or less cover of an herbaceous layer (Figure 2-29; right photo). Some mapped areas do include shrubs but they are not dominant. Most of these areas appear to be composed of tailings which may be inhibiting herbaceous vegetation growth. These areas also include decadent forested areas with bare ground. Common tree species within this vegetation community include lodgepole pine, subalpine fir, and Engelmann spruce. Soils consist of visible surface contamination up to 8 inches underlain by a buried loam surface layer and sandy loam to coarse sand subsoil.

Figure 2-29. Forested area with upland herbaceous vegetation in the understory (left), and a forested area with bare ground (right).

Colonizing Bare Ground

This vegetation community consists of areas along channels where deposition has buried vegetation, creating bare ground that is now being colonized by species including lodgepole pine, Engelmann spruce, sitka alder, narrowleaf willow, Booth's willow, water birch (*Betula occidentalis*), and black cottonwood *(Populus balsamifera)* (Figure 2-30; left photo). This vegetation community is different from bare ground in that there is at least 30% cover of colonizing vegetation.

Bare Ground

This vegetation community consists of areas directly adjacent to the main channel where vegetation is not growing (Figure 2-30; right photo). This could be due to the geomorphic position where this vegetation community occurs where it is frequently scoured by flood events, or it could be because sediment being deposited along the channel is contaminated. This vegetation community is also found as patches not along the channel but within forested emergent wetland and forested upland herbaceous vegetation communities.

Figure 2-30. Colonizing Bare Ground vegetation community with conifers and a few cottonwoods beginning to colonize the area (left), and a Bare Ground area where no vegetation is becoming established (right).

Emergent Marsh

This vegetation community consists of wetlands dominated by emergent vegetation including Northwest Territory sedge, water sedge, field horsetail, and *Sphagnum* moss (Figure 2-31). Some willows are present but are not dominant. Soils generally consist of 12 inches of mucky mineral underlain by clay loam subsoil. This community type is found in patches within a forested matrix in addition to the large wetland complex.

Fen

This vegetation community is characterized by wetlands that have greater than 15.7 inches (40 cm) of accumulated peat. Fen wetlands were found within the large wetland complex and include areas of forested, shrub, and emergent wetland plant communities (Figure 2-31; right photo). Dominant vegetation includes lodgepole pine, Northwest Territory sedge, birch (*Betula* spp.), and *Sphagnum* spp. Fens are a unique wetland ecosystem that have perennially saturated soils attributed to constant groundwater inflow and provide a critical refugium for many plants and animal species specifically adapted to this wetland type.

Figure 2-31. Emergent Marsh within a larger forested area (left) and a Fen wetland area within a large wetland complex that is dominated by sedges and willow (right).

Scrub Shrub Wetland

This vegetation community includes any wetland with 30% or more shrub canopy cover. Dominant species include bebb willow, Booth's willow, Drummond's willow, water birch, and sitka alder. Typical vegetation in the herbaceous layer includes Northwest Territory sedge, blister sedge (*Carex vesicaria)*, Chamisso sedge (*Carex pachystachya)*, and tufted hairgrass (*Deschampsia cespitosum*) (Figure 2-32; left photo). This vegetation community mostly occurs in the northeast (upstream) portion, and west (downstream) end of the marsh area.

Filled Scrub Shrub Wetland

This community is similar to the Scrub Shrub Wetland community described above except that it has deep layers of visible deposited contamination (Figure 2-32; right photo). These areas probably were once similar in condition to the scrub shrub wetlands in the wetter marsh areas, but they are now barely functioning as wetlands. Contaminated sediments have buried much of the vegetation in these areas, and wetland hydrology has been modified.

Figure 2-32. Scrub Shrub Wetland vegetation community dominated by willows (left) and Filled Scrub Shrub vegetation community (right).

Mike Horse Riparian

A narrow fringe of riparian vegetation borders both sides of Mike Horse Creek. Dominant vegetation includes Douglas fir, lodgepole pine, and black cottonwood in the overstory with a shrub understory primarily consisting of diamondleaf willow, Bebb willow, and Sitka willow (*Salix sitchensis*). Vegetation in the herbaceous stratum includes raceme pussytoes (*Antennaria racemosa*), field horsetail, and white spiraea (*Spiraea betulifolia*).

Mike Horse Dry Conifer Slope

This vegetation community occurs on south facing slopes on the west side of Mike Horse Creek. Drier conditions are common on slopes with a south facing aspect and these conditions are reflected in the vegetation communities that are present. Dominant vegetation in the overstory includes lodgepole pine and Douglas-fir with a shrub understory dominated by common juniper (*Juniperus communis*) and dwarf bilberry. Dominant vegetation in the herbaceous stratum includes white spiraea and common beargrass.

Beartrap Creek Riparian

A mixed conifer and shrub riparian zone interspersed with bare ground borders Beartrap Creek downstream of the dam. Dominant vegetation in the overstory includes Douglas-fir and lodgepole pine with a shrub understory consisting of Drummond's willow, Sitka willow, Booth's willow, and bebb willow. Dominant vegetation in the herb stratum includes water sedge, field horsetail, white bog orchid (*Platanthera dilatata*), and largeleaf avens (*Geum macrophyllum*).

Beartrap Creek Moist Conifer Slope

This vegetation community occurs on east facing slopes on the west side of Beartrap Creek. Dominant vegetation incudes subalpine fir, Douglas-fir, and lodgepole pine in the overstory with a sparse understory consisting of white spiraea, twinberry honeysuckle (*Lonicera involucrata*), and common juniper.

As noted above, evaluating existing vegetation communities provides information about which communities are providing functions that should be replicated through restoration actions, and which communities should be preserved where possible. Table 2-8 describes functions and values within a subset of highly functioning existing vegetation communities and identifies which of these communities should be preserved where possible, and which should be used as models for restoration. Specific models for restoration that integrate plant species composition with geomorphology and hydrology are called cover types, and these are described in Section 3 of this report.

Table 2-8. Summary of vegetation community types found in the project area, including ecological status, function, and recommendations to restore versus preserve.

Existing Vegetation Community	Functions/Values	Restore/Preserve
Colonizing depositional (vegetated bar)	This community type includes depositional areas along the channel that are being colonized by herbaceous and woody species. The primary function of this community type is to promote riparian plant community succession. These community types would occur on the inside of meander bends along the main channel and side channels.	Restore
Fen	This community type includes wetland areas with 40 cm or greater of accumulated peat and are groundwater dependent. This community type supports a range of floodplain and aquatic habitat functions including natural attenuation of metals, maintenance of surrounding water tables, increased biodiversity, and habitat for rare or endangered species. Because it takes centuries for this existing cover type to develop, preservation of these areas is recommended.	Preserve
Emergent Wetland	This community type includes herbaceous wetland plant communities dominated by sedge, rush or wetland forb species. This community type supports a range of floodplain and aquatic habitat functions including floodplain and streambank stability, groundwater recharge, reduced sedimentation, filtering of nutrients and sediments, and increased biodiversity of plants and animals. This community type would occur in low areas of the floodplain, as a component of streambanks and large wetland complex.	Restore/Preserve

Table 2-8. Summary of vegetation community types found in the project area, including ecological status, function, and recommendations to restore versus preserve.

Existing Vegetation Community	Functions/Values	Restore/Preserve
Shrub Wetland	This community type includes woody wetland plant communities dominated by willows and alder. This community type supports a range of floodplain and aquatic habitat functions including groundwater recharge, moderating stream flow, filtering of nutrients and sediment, and increased biodiversity of plants and animals. This community type would occur in low areas of the floodplain and as a component of the large wetland complex.	Restore/Preserve
Forested Emergent Wetland	This community type includes forested wetlands with an understory dominated by sedges, wetland grasses, and *Sphagnum* moss located along the margins of existing fen and emergent wetlands. This community type supports a range of floodplain and aquatic habitat functions including water storage and groundwater recharge, increased primary productivity, and increased biodiversity of plants and animals. Because it takes a long time for this existing cover type to develop, preservation of these areas is recommended.	Preserve
Forested Shrub Wetland	This community type includes forested wetlands with an understory dominated by woody species located along the margins of existing fen and emergent wetlands. This community type supports a range of floodplain and aquatic habitat functions including water storage and eventual groundwater recharge, increased primary productivity, and increased biodiversity of plants and animals. Because it takes a long time for this existing cover type to develop, preservation of these areas is recommended.	Preserve
Mike Horse/Beartrap Riparian	These community types include riparian areas adjacent to Mike Horse and Beartrap Creeks that are dominated by willows and alder. This community type supports ecological functions including increased primary productivity, filtering of nutrients and sediment, bank stabilization, and increased biodiversity of plants and animals. This community would occur within the bankfull floodplain of Mike Horse and Beartrap Creeks.	Restore

Table 2-8. Summary of vegetation community types found in the project area, including ecological status, function, and recommendations to restore versus preserve.

Existing Vegetation Community	Functions/Values	Restore/Preserve
Upland Conifer	This community type includes drier conifer forests dominated by fir, spruce, and pine. This community type supports floodplain and riparian function by providing a buffer and habitat for species utilizing the riparian corridor. This community type represents a transition from the floodplain to adjacent uplands and typically occurs on high terrace features and side slopes.	Restore

3 Design Criteria

3.1 Introduction

This section presents the criteria used to develop the preliminary design. The results of the design investigations described in Section 2 of this report provide the basis for the criteria summarized in the following sections.

3.2 Restoration Constraints

During the preliminary design process, several constraints to restoration were identified. A constraint is generally defined as an aspect of the existing or future site conditions that cannot be changed or modified, and must be taken into consideration during the design process. Sheet 4.1 in Appendix A includes a map of existing utilities and infrastructure in the project area.

3.2.1 Reach 1 Mining Infrastructure

In Reach 1 Mike Horse Creek, mining infrastructure including mine waste piles, detention basins, buildings, exposed ore bodies, waterlines, and access roads constrain the valley width and limit restoration potential. While remediation may result in removing or relocating some of these features, restoration acknowledges that some infrastructure will remain in place in order to collect and treat acid mine drainage that will likely exist in perpetuity given the underlying geology and highly altered valley morphology. As described in Section 4.1, excavation and remedial extents are still being refined in Reach 1 Mike Horse Creek. The approach to restoration will primarily focus on limiting sedimentation to Mike Horse Creek from adjacent mineralized hillslopes through a variety of revegetation and slope stabilization techniques.

3.2.2 Reach 3 Adit Drains, Temporary Construction Haul Road, and Diversion

In Reach 3 Lower Beartrap Creek, along the east side of the valley, two adits are present: the Flossie Louise Mine and Red Wing Mine. These adits are producing acid mine drainage to Lower Beartrap Creek. This condition is anticipated to persist into the future following restoration. The restoration plan will separate this water from the channel to the greatest extent feasible through construction of a series of stepped wetlands (Appendix A, Sheet 7.0). In addition to the adits, a temporary diversion and haul road will be constructed in the Lower Beartrap Creek valley. The combination of the adit locations, and need for both a construction haul road and diversion, limits the belt width available for restoration in the upper portion of Reach 3. Presently, various alternatives are being explored to minimize these constraints to restoration.

3.2.3 Reach 4 Water Treatment Plant

A variety of infrastructure exists in Reach 4 to support ongoing operations at the water treatment plant. A detailed description of the existing infrastructure is provided in Section 3.3 of DEQ’s 2013 draft conceptual removal plan. A detailed plan will be prepared prior to remedial and restoration activities to address this infrastructure in order to minimize impact to the water treatment plant operations.

The footprint of the water treatment plan limits the width of the valley at the upper end of Reach 4 (Appendix A, Sheet 8). In order to maximize the width of available floodplain for restoration, DEQ has identified preliminary measures including removing a portion of Cell 4 and the existing laydown yard located on the west side of the valley. These actions will provide a maximum meander belt width of approximately 85 feet. Restoration design criteria for this section of Reach 4 will balance restoration needs with the requirement to minimize risk to the water treatment plant infrastructure. This may result in modifying some elements of the final restoration design or developing site-specific design criteria for this section of Reach 4.

3.2.4 Cultural Resources

Cultural resources have been surveyed and mapped in the project area. Final restoration planning will be coordinated with the Helena National Forest and State Historic Preservation Office.

3.3 Geomorphic Design Criteria

This section describes the geomorphic design criteria for the UBMC. The criteria emphasize creating a range of channel geometries that are appropriately suited to the desired future morphology of the valley bottom landforms and stream types in the UBMC.

3.3.1 Design Flows

Section 2.1 of this report describes the methods and results of the channel forming discharge and flood frequency analysis completed for the UBMC project area. This information forms the basis for the design discharge values summarized in Table 3-1.

Table 3-1. Summary of UBMC flood frequency discharge estimates (in cfs) by reach and major tributary.

Reach	Recurrence Interval (yrs)				
	1.5	**10**	**25**	**50**	**100**
Reach 1 Mike Horse Creek	16	19	39	64	104
Reach 2 Upper Beartrap Creek	25	59	111	175	274
Reach 3 Lower Beartrap Creek	41	75	181	455	677
Anaconda Creek	55	104	191	296	455
Reach 4 Upper Blackfoot River	90	158	283	432	656
Shaue (Shave) Gulch	55	107	199	309	476
Reach 5 Middle Blackfoot River	145	254	449	677	1015
Reach 6 Lower Blackfoot River	180	330	577	864	1287

3.3.2 Channel Cross-Section Dimensions and Planform Design Criteria

Section 2.2 of this report describes the methods used to develop channel cross-section and planform design criteria. At the reach-scale, the channels are designed to accommodate the estimated bankfull discharge and to hydrologically interact with the floodplain at the incipient point of flooding. Floodplain and terraces will convey flows greater than bankfull including the estimated Q100 recurrence interval discharge. The channel shape will exhibit stage-progressive geometry and exhibit a range of natural variability in order to support characteristics of a natural system. Design bankfull and recurrence interval flood flows are summarized in Table 3-1.

The design channels will integrate planform and longitudinal profile variability. Design channel features include riffle, run, pool, and glide channel units in order to create complex habitats with variable depth, velocity, and substrate characteristics. The design channel alignments will exhibit a variety of planform patterns depending on slope and valley confinement, and will include ranges for all geomorphic variables. Planform metrics used to develop geometry for the channel alignments include meander wavelength, belt width, radius of curvature and sinuosity. Schematics illustrating the terminology related to planform geometry for a typical meandering, riffle-pool channel type are shown in Figure 3-1.

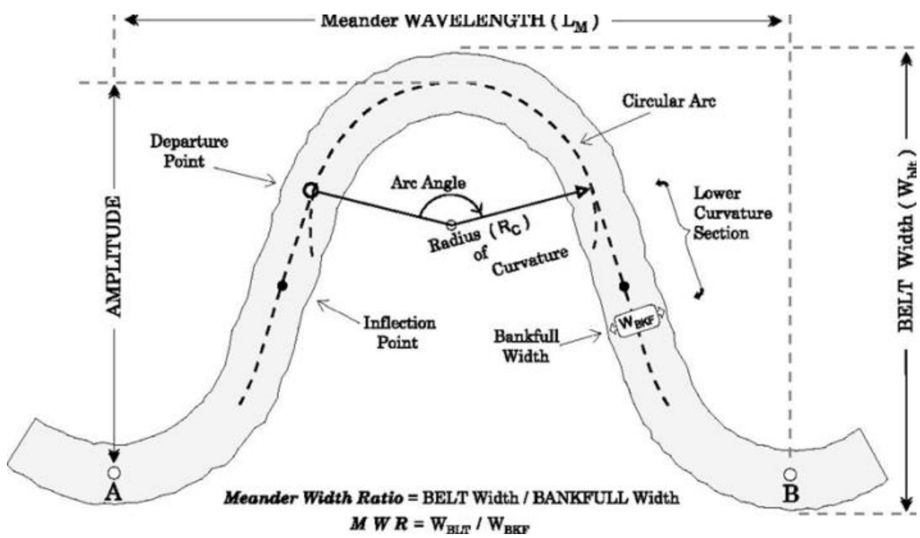


Figure 3-1. Schematic illustrating terminology for meander planform geometry (Rosgen 1996 after Williams 1986).

The following tables summarize bankfull channel cross-section and planform design criteria by reach.

Reach 1 Mike Horse Creek

Channel cross-section and planform design criteria for Reach 1 Mike Horse Creek are summarized in Tables 3-2 and 3-3, respectively. The desired channel morphology is a step-pool, boulder dominated A2 stream type.

Table 3-2. Reach 1 bankfull channel cross-section design criteria (in feet).

Dimension	Channel Unit			
	Riffle	Run	Pool	Glide
Area	6.0	6.6	8.4	7.2
Width/Depth Ratio Range	11.0 9.0-13.0	N/A	N/A	N/A
Bankfull Width Range	8.0 7.3-8.8	8.0 6.4-9.6	9.6 8.8-10.4	9.6 8.8-10.4
Average Depth Range	0.7 0.7-0.9	0.7 0.6-0.8	1.2 1.2-2.0	0.7 0.6-0.8
Maximum Depth Range	1.0 0.9-1.1	1.2 1.0-1.3	1.9 1.4-2.3	1.2 1.0-1.4

Table 3-3. Reach 1 channel planform design criteria (in feet).

Dimension	Value
Radius of Curvature Range	38.0 28.0-48.0
Meander Length Range	112.0 80.0-144.0
Meander Belt Width Range	36.0 24.0-48.0
Sinuosity Range	1.1 1.0-1.2

Reach 2 Upper Beartrap Creek

Channel cross-section and planform design criteria for Reach 2 Upper Beartrap Creek are summarized in Tables 3-4 and 3-5, respectively. The desired channel morphology is a moderately entrenched, step-pool, boulder dominated B2 stream type with interspersed riffles.

Table 3-4. Reach 2 bankfull channel cross-section design criteria (in feet).

Dimension	Channel Unit			
	Riffle	Run	Pool	Glide
Area	9.5	10.5	13.3	11.4
Width/Depth Ratio Range	12.0 10.0-14.0	N/A	N/A	N/A
Bankfull Width Range	10.7 9.7-11.5	10.7 8.5-12.8	12.3 11.7-12.8	12.8 11.7-13.9

Table 3-4. Reach 2 bankfull channel cross-section design criteria (in feet).				
Dimension	**Channel Unit**			
	Riffle	**Run**	**Pool**	**Glide**
Average Depth	0.9	0.8	1.3	0.8
Range	0.8-1.0	0.6-1.0	0.9-1.8	0.7-1.0
Maximum Depth	1.2	1.4	2.2	1.5
Range	1.1-1.3	1.2-1.6	1.7-2.8	1.2-1.7

Table 3-5. Reach 2 channel planform design criteria (in feet).	
Dimension	**Value**
Radius of Curvature	50.8
Range	37.5-64.2
Meander Length	149.8
Range	107.0-192.6
Meander Belt Width	48.2
Range	32.1-64.2
Sinuosity	1.1
Range	1.0-1.2

Reach 3 Lower Beartrap Creek

Channel cross-section and planform design criteria for Reach 3 Lower Blackfoot River are summarized in Tables 3-6 and 3-7, respectively. The desired channel morphology is a moderately entrenched, riffle-pool, cobble dominated B3 stream type with irregularly spaced riffles.

Table 3-6. Reach 3 bankfull channel cross-section design criteria (in feet).				
Dimension	**Channel Unit**			
	Riffle	**Run**	**Pool**	**Glide**
Area	16.0	17.6	22.4	19.2
Width/Depth Ratio	16.0	N/A	N/A	N/A
Range	14.0-20.0			
Bankfull Width	16.0	16.0	18.4	19.2
Range	15.0-17.9	12.8-19.2	17.6-20.8	17.6-20.8
Average Depth	1.0	0.9	1.5	1.0
Range	0.9-1.1	0.8-1.0	1.0-2.0	0.8-1.1
Maximum Depth	1.3	1.6	2.5	1.7
Range	1.2-1.4	1.3-1.8	1.9-3.1	1.4-1.9

Table 3-7. Reach 3 channel planform design criteria (in feet).	
Dimension	**Value**
Radius of Curvature	76.0
Range	56.0-96.0
Meander Length	224.0
Range	160.0-288.0
Meander Belt Width	72.0
Range	48.0-96.0
Sinuosity	1.3
Range	1.2-1.4

Reach 4 Upper Blackfoot River

Channel cross-section and planform design criteria for Reach 4 Upper Blackfoot River are summarized in Tables 3-8 and 3-9, respectively. The desired channel morphology is a moderately to slightly entrenched, riffle-pool, cobble dominated B3 and C3b stream type.

Table 3-8. Reach 4 bankfull channel cross-section design criteria (in feet).				
Dimension	**Channel Unit**			
	Riffle	**Run**	**Pool**	**Glide**
Area	32.0	35.2	44.8	38.4
Width/Depth Ratio	21.0	N/A	N/A	N/A
Range	18.0-24.0			
Bankfull Width	25.9	29.8	31.1	31.1
Range	24.0-27.7	23.3-33.7	23.3-33.7	31.1-33.7
Average Depth	1.2	1.2	1.7	1.5
Range	1.1-1.3	1.0-1.5	1.1-2.1	1.1-1.7
Maximum Depth	1.9	2.2	3.1	2.2
Range	1.6-2.1	2.0-2.5	2.3-3.6	1.9-2.5

Table 3-9. Reach 4 channel planform design criteria (in feet).	
Dimension	**Value**
Radius of Curvature	123.0
Range	90.7-155.4
Meander Length	362.6
Range	259.0-466.2
Meander Belt Width	116.6
Range	77.7-155.4
Sinuosity	1.4
Range	1.2-1.5

Reach 5 Middle Blackfoot River – C3 and C4 Stream Type

Channel cross-section and planform design criteria for Reach 5 Middle Blackfoot River (C stream type) are summarized in Tables 3-10 and 3-11, respectively. The desired channel morphology is a slightly entrenched, riffle-pool, cobble and gravel dominated C3 and C4 stream type.

Table 3-10. Reach 5 bankfull channel cross-section design criteria for C4 stream type (in feet).

Dimension	Channel Unit			
	Riffle	**Run**	**Pool**	**Glide**
Area	48.0	52.8	67.2	57.6
Width/Depth Ratio Range	24.0 22.0-26.0	N/A	N/A	N/A
Bankfull Width Range	33.9 32.5-35.3	33.9 30.5-40.7	40.7 30.5-44.1	40.7 37.3-44.1
Average Depth Range	1.4 1.3-1.5	1.7 1.3-2.0	1.6 1.1-1.8	1.7 1.3-2.0
Maximum Depth Range	2.0 1.7-2.3	2.5 2.0-2.8	3.8 2.7-4.9	2.5 1.8-3.1

Table 3-11. Reach 5 channel planform design criteria for C4 stream type (in feet).

Dimension	Value
Radius of Curvature Range	123.9 95.0-152.7
Meander Length Range	475.2 339.4-610.9
Meander Belt Width Range	407.3 135.8-678.8
Sinuosity Range	1.7 1.5-1.8

Reach 5 Middle Blackfoot River – E4 Stream Type

Channel cross-section and planform design criteria for Reach 5 Middle Blackfoot River (E4 stream type) are summarized in Tables 3-12 and 3-13 respectively. The desired channel morphology is a non-entrenched, low width to depth ratio, riffle-pool, gravel dominated E4 stream type.

Table 3-12. Reach 5 bankfull channel cross-section design criteria for E4 stream type (in feet).

Dimension	Channel Unit			
	Riffle	Run	Pool	Glide
Area	38.0	41.8	53.2	45.6
Width/Depth Ratio Range	9.0 8.0-10.0	N/A	N/A	N/A
Bankfull Width Range	18.0 15.1-19.5	17.1 16.2-18.0	18.0 16.2-19.8	19.8 18.0-23.4
Average Depth Range	2.1 1.9-2.5	2.3 1.7-2.7	2.3 2.7-3.8	2.1 1.9-2.3
Maximum Depth Range	3.0 2.5-3.2	3.6 3.4-3.8	6.1 4.7-6.3	3.2 3.0-3.4

Table 3-13. Channel planform design criteria for E4 stream type (in feet).

Dimension	Value
Radius of Curvature Range	65.7 50.4-81.0
Meander Length Range	252.0 180.0-324.0
Meander Belt Width Range	216.0 72.0-360.0
Sinuosity Range	1.8 1.5-2.0

3.4 Channel Hydraulic Design Criteria

Hydraulic investigations described in Section 2.3 of this report form the basis for the design criteria presented in this section. The intent of the channel hydraulic design is to create channels and streambank toes that will support sustainable habitat conditions, support streambank restoration treatments, maintain channel connection with the floodplain at the approximate bankfull discharge, and provide sediment transport continuity through the project area.

At this stage of planning, design discharges have not been selected for evaluating project stability, including channel and floodplain performance. Therefore, a range of results are presented that can be used to help guide the design of riverbed and streambank toe gradations. The D84 size class of the riverbed gradation is considered the threshold particle size for mobility. Riverbed fill material sized smaller than the D84 would represent the 'mobile matrix' and would be constructed of graded alluvium ranging in size from sands and small gravels up to the estimated D84 size class. Riverbed material greater than the D84 size class would represent the riverbed 'framework' and would be comprised of immobile alluvium to provide vertical bed stability and maintain floodplain connection, particularly in the higher gradient, transport dominated reaches of the UBMC. This general concept is illustrated in Sheet 14.5 in Appendix A.

There are several factors to consider when selecting the channel hydraulic design criteria. These include:

- <u>Risk and Stability</u>: The design should balance the need for short-term stability with long-term ecological function. Projects designed for higher recurrence interval flows (e.g. Q100) are resistant to floods and other natural disturbances to the detriment of the long-term ecological function of the channel and floodplain ecosystem, and the aquatic habitat environment. Projects designed for lower recurrence interval flows (e.g. Q10) are less resistant to floods and other disturbances which can increase the risk of structural failure in the short-term. Short-term structural failure can have significant implications on meeting project goals and objectives over time. From a restoration perspective, short-term structural failure can mean either project failure or success, depending on how risk is defined in terms of balancing structural stability with ecological function.
- <u>Natural Channel Armoring</u>: The bed surface of stream channels is typically armored or coarser than the subsurface material as a result of natural bed material sorting. This condition influences channel hydraulics and determines the sediment available for transport (Wilcock et al. 2005). Reconstructed stream channels typically require multiple runoff events to naturally sort and armor the bed surface of the channel. Without the appropriate riverbed gradation or armor layer, the channel can be at risk of downcutting particularly if the project is subject to a flood within the first few years following construction. An established bed armor layer is critical for maintaining vertical channel stability, particularly in high energy fluvial environments such as the UBMC. For this reason, channels are sometimes constructed of slightly larger bed material than what is needed to provide a stable bed once material has been naturally sorted.
- <u>Vegetation</u>: The channel design approach for the UBMC is in part based on natural channel design philosophy which relies on streambank and floodplain vegetation to provide long-term planform stability to the channel. Channel design criteria can be used to specify materials that provide short-term, interim stability to allow for streambank and floodplain vegetation to establish and mature. This design emphasizes criteria that reduce short-term failure risk and increase the likelihood of success.
- <u>Response Variability</u>: Geomorphic and vegetation response to floods and other natural disturbances can vary significantly by stream and valley type, topographic position in the watershed, success of revegetation treatments, and others. Design criteria can be developed at the reach-scale to account for this variability. For example, it may be appropriate to design for a higher recurrence interval flow (e.g. Q50) in the steeper, more confined reaches of the UBMC, whereas developing criteria for lower recurrence

interval flows (e.g. Q25) may be appropriate in the lower reaches because flood energy can be dissipated over a broad floodplain surface.

Hydraulic modeling output for the preliminary design conditions is included in Appendix C. Summary tables and exhibits for Reaches 2, 3, 4 and 5 hydraulic variables including depth, velocity, and shear stress are included for both the active channel and overbank (floodplain areas). Results are presented for Q10, Q25 and Q100 flood recurrence interval flows.

The following tables summarize a range of potential hydraulic design criteria for flood recurrence interval flows. These criteria should be evaluated carefully as they will form the basis for the channel stability design criteria for all phases of restoration in the UBMC.

Table 3-14. Reach 2 hydraulic design criteria for a range of flood recurrence interval flows.

Variable	**Recurrence Interval (yrs)**				
	1.5	**10**	**25**	**50**	**100**
Depth (ft)	0.8	1.3	1.6	1.8	2.1
Velocity (fps)	2.9	3.9	4.5	5.0	5.5
Shear Stress (lbf/ft^2)	1.9	2.9	3.7	4.3	4.9
Average Mobile Particle Size (mm)	240	364	460	534	611

Table 3-15. Reach 3 hydraulic design criteria for a range of flood recurrence interval flows.

Variable	**Recurrence Interval (yrs)**				
	1.5	**10**	**25**	**50**	**100**
Depth (ft)	0.9	1.2	1.6	1.9	2.2
Velocity (fps)	3.2	3.8	4.6	5.1	5.7
Shear Stress (lbf/ft^2)	1.7	2.3	3.0	3.6	4.2
Average Mobile Particle Size (mm)	216	283	377	450	524

Table 3-16. Reach 4 hydraulic design criteria for a range of recurrence interval flood flows.

Variable	**Recurrence Interval (yrs)**				
	1.5	**10**	**25**	**50**	**100**
Depth (ft)	1.1	1.4	1.8	2.0	2.3
Velocity (fps)	3.6	4.2	4.7	5.3	5.9
Shear Stress (lbf/ft^2)	1.3	1.6	1.9	2.2	2.7
Average Mobile Particle Size (mm)	161	197	236	281	337

Table 3-17. Reach 5 hydraulic design criteria for a range of recurrence interval flood flows (C4 stream type).

Variable	**Recurrence Interval (yrs)**				
	1.5	**10**	**25**	**50**	**100**
Depth (ft)	1.3	1.7	2.2	2.5	2.9
Velocity (fps)	4.0	4.6	5.2	5.8	6.5
Shear Stress (lbf/ft^2)	0.8	1.0	1.1	1.3	1.6
Average Mobile Particle Size (mm)	102	126	144	170	202

Table 3-18. Reach 5 hydraulic design criteria for a range of recurrence interval flood flows (E4 stream type).

Variable	Recurrence Interval (yrs)				
	1.5	10	25	50	100
Depth (ft)	1.9	2.3	2.8	3.0	3.2
Velocity (fps)	4.8	5.7	5.0	5.8	6.4
Shear Stress (lbf/ft^2)	0.8	1.1	0.8	1.0	1.2
Average Mobile Particle Size (mm)	100	138	100	131	156

3.5 Floodplain Design Criteria

3.5.1 Introduction

The intent of the floodplain design is to create a floodplain that is hydrologically connected to the stream channel and therefore supports a mosaic of riparian and wetland plant communities represented by the cover types described in Section 3.8 of this report. In general, all reaches include a bankfull floodplain. Other features that occur in a subset of reaches include transition areas, point bars, low terrace features, off-channel wetlands and depressions, and side channels.

3.5.2 Floodplain Features

Floodplain features are described below. Elevations for each feature are described in terms of bankfull elevation, which corresponds to the average water surface elevation during the 1.5 year return flow. Table 3-19 provides a summary of design criteria for each feature, and which floodplain feature would occur in each reach.

Bankfull Floodplain

The bankfull floodplain represents the area immediately adjacent to the channel. This feature is located between 0 and 0.5 ft above the bankfull elevation and represents the area that is frequently flooded (approximately every one or two years) and where groundwater is present in the rooting zone throughout much of the growing season in most years. This area varies in width; in Reach 2, Upper Beartrap Creek, the bankfull floodplain is a narrow band (approximately 10 ft wide) along the channel; while in Reach 5, the bankfull floodplain occupies most of the grading extents.

Transition Areas

Transition areas are present in reaches upstream of the Anaconda Creek confluence with Beartrap Creek. The transition area would occupy elevations between 0.5 ft above bankfull and the toe of adjacent upland slopes. The transition area represents the outer zone of the floodplain where a combination of flooding and groundwater conditions will create hydrology that supports riparian vegetation.

Point Bars

Point bars would be present in Reach 4, Upper Blackfoot River, and in the upper portion of Reach 5, Lower Blackfoot River. Point bars occupy elevations between base flow and bankfull, and slopes range from 10:1 in Reach 4 to 15:1 in the upper portion of Reach 5. Design criteria for point bar slopes strike a balance between providing depositional areas where willows and cottonwoods can establish, and creating sufficient hydraulic compression through pools which is necessary to drive sediment transport given the relatively flat channel slope through pool features. Overall, as the channel gradient lessens, point bar slopes become flatter.

Low Terrace

Low terraces would be present in the lower portion of Reach 3, and throughout Reach 4. This feature occupies elevations between 0.5 ft and 2 ft above bankfull and is outside the meander belt width of the channel. The outer edge of this feature ties in with upland areas and the toe of adjacent slopes. Side channels and off-channel wetlands would be located on the low terrace in reaches where low terrace is present.

Off-channel Wetlands and Swales

Off-channel wetlands and swales are present in Reaches 3, 4 and 5. They are located at elevations between bankfull and two feet below bankfull where they intercept groundwater during a portion of the year. Off-channel wetlands are subtle topographic features in the floodplain; maximum steepness of side slopes is 10:1, and these features would be located outside of the meander belt width. Swales are smaller features than wetlands and would occupy elevations between the floodplain surface and approximately two feet below the floodplain surface. Slopes would be variable, and swales would be located at least one bankfull width from the channel. These areas would function to provide topographic complexity resulting in flood energy dissipation, sediment and nutrient trapping, and as suitable zones for concentrated planting where the water table is close to the surface.

Side Channels

Side channels are ephemeral channels that would connect the main stream channel with off-channel wetlands at approximate bankfull flows. Side channel dimensions will be determined as part of final design once specific hydraulic metrics have been developed for each reach.

Table 3-19. Design criteria for floodplain features and associated reaches.

Treatment for	Design Criteria	Applicable Reaches
Bankfull floodplain	0 to 0.5 ft above bankfull; occupies zone adjacent to stream channel.	All reaches
Transition areas	0.5 ft above bankfull and higher, extending to the toe of adjacent hillslopes.	Reaches 2 and 3

Table 3-19. Design criteria for floodplain features and associated reaches.

Treatment for	Design Criteria	Applicable Reaches
Point bar	Base flow to bankfull elevation range; slopes range from 10:1 to 15:1 (Reaches 4 and 5 respectively).	Reach 4; upper portion of Reach 5
Low terrace	0.5 ft above bankfull to 2.0 ft above bankfull.	Reaches 3 and 4
Off-channel wetlands	Occupy elevations between 0 and 2 ft below bankfull and are present outside belt width. Slopes are 10:1 or gentler.	Reaches 3, 4 and 5
Swales	Range from floodplain surface to 2 ft below surface, and are a minimum of one bankfull width from the channel. Slopes are variable.	Reaches 3, 4 and 5
Side channels	Dimensions to be determined; active at approximately bankfull flows.	Reaches 3, 4 and 5

3.6 Streambank Design Criteria

3.6.1 Introduction

Streambank designs are intended to provide short term planform stability while floodplain vegetation develops. Streambanks are intended to be deformable once floodplain vegetation has matured sufficiently such that vegetation can begin to function as a morphological control on new channels that develop. To accomplish this long-term deformability, streambanks will be constructed using native material such as rock and wood, combined with biodegradable fabrics. Designs are based on the following criteria:

- Where streambanks require a constructed toe to support short term plan form stability, the toe will be designed to withstand shear stress associated with the selected design event and shear forces in the channel.
- Streambank slopes will be 1:5 to 1 or steeper except on point bars where slopes are described in Section 3.5 Floodplain Design Criteria.
- Where C channel morphology is present (Reach 4), outside meanders will be super-elevated so the top of bank is approximately 0.5 ft above the bankfull elevation (1.5 year water surface elevation). This reflects natural morphology in these stream types and is intended to keep bankfull flows within the channel and force incipient flooding

onto the point bar. Bank heights in other stream types would be constructed to the bankfull elevation (1.5 year return flow water surface elevation).

3.6.2 Streambank Treatments

Streambank treatments are described below, and typical streambank treatment layouts are shown in Appendix A, Sheets 14.0 to 14.4. In the following section, streambank treatments are generally described in order from softest (treatments that would be placed on depositional or passive flow areas) to hardest (treatments that would be placed in high shear stress areas such as outer meanders). As described above, all treatments are intended to be deformable in the long term. Table 3-20 describes how each streambank treatment would be applied in Reaches 2, 3, 4 and 5.

Vegetated Brush Fascine

The intent of the vegetated brush fascine structure (Appendix A, Sheet 14.4) is to provide site conditions directly along the channel that are suitable for growing riparian vegetation. The vegetated brush fascine provides bank strength in the short-term until mature riparian vegetation establishes and provides long-term streambank stability. The structure also provides channel margin roughness and near-bank aquatic habitat complexity. The Type 1 structure is used in zones of low to moderate shear stress along the channel planform including outside meander streambanks, and riffle, run and glide channel units. The structure is used in sequence with other streambank treatments and includes a constructed toe. The Type 2 structure provides similar function to the Type 1 structure but is used in zones of low shear stress, or passive margins. The Type 2 structure does not include a constructed toe and is placed along inside meander streambanks (e.g. point bars and meander cores) to increase channel boundary roughness and support riparian vegetation establishment.

Vegetated Wood and Brush Fascine

The intent of the vegetated wood and brush fascine structure (Appendix A, Sheet 14.4) is to provide site conditions directly along the channel that are suitable for growing riparian vegetation. The vegetated brush fascine provides bank strength in the short-term until mature riparian vegetation establishes and provides long-term streambank stability. The structure also provides channel margin roughness and near-bank aquatic habitat complexity. The Type 1 structure includes a constructed toe and is used in zones of high shear stress along the channel planform including outside meander streambanks, riffles, and run and glide channel unit transitions. The structure is used in sequence with other streambank treatments and includes a constructed toe. The Type 2 structure provides similar function to the Type 1 structure but is used in zones of low shear stress, or passive margins. The Type 2 structure does not include a constructed toe and is placed along inside meander streambanks (e.g. point bars and meander cores) to increase channel boundary roughness and support riparian vegetation establishment.

Vegetated Soil Lift

The intent of the vegetated soil lift structure (Appendix A, Sheet 14.2) is to provide site conditions directly along the channel that are suitable for growing riparian vegetation. The vegetated soil lift provides bank strength in the short-term until mature riparian vegetation establishes and provides long-term streambank stability. The structure incorporates high density coir logs to support the bank shape, increase soil moisture retention and extend the duration of the growing season. The structure incorporates wood and brush layering to increase channel margin roughness and provide near-bank aquatic habitat complexity. The structure includes a constructed toe to provide streambank stability. Over a five to seven year period, the fabric will decompose and the rooting strength of established vegetation is intended to maintain low bank erosion rates. Type 1 is a one layer vegetated soil lift (one foot thick) and is typically located along shallower sections along the channel. Type 2 is a two layer vegetated soil lift (two feet thick) and would be used alongside pools where the channel is deeper. Both Type 1 and Type 2 vegetated soil lifts would be installed so the top of the structure coincides with the bank height.

Large Wood Structure

The intent of the large wood structure is to provide short-term streambank protection and stabilization by re-directing flow away from the channel margins, dissipating energy, reducing near-bank stress, and maintaining lateral scour pools. The structure also provides bank strength to support riparian vegetation establishment along outside meander streambanks. The structure incorporates several tiers of brush and wood to increase channel margin roughness and provide near-bank aquatic habitat complexity. The structure includes a constructed toe to provide stability, and is typically used in sequence with other streambank structures.

Table 3-20. Streambank treatment applications by reach.

Streambank Treatment	Reach 2	Reach 3	Reach 4	Reach 5
Vegetated Brush Fascine – Type 2	N/A	N/A	N/A	Located along inside meanders of downstream (low-gradient) portion of Reach 5. Provides channel margin roughness and complexity, and supports riparian vegetation establishment. Does not include a constructed toe.

Table 3-20. Streambank treatment applications by reach.

Streambank Treatment	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**
Vegetated Brush Fascine – Type 1	N/A	N/A	N/A	Located along riffles in downstream (low-gradient) portion of Reach 5. Provides channel margin roughness and complexity, and supports riparian vegetation establishment. Includes constructed toe to resist scour.
Vegetated Wood and Brush Fascine – Type 2	N/A	Provides channel margin roughness and complexity along inside meanders adjacent to pools, and supports riparian vegetation growth along the streambank. Does not include a constructed toe.	Provides channel margin roughness and complexity along riffles and defines transitions to point bars. Also used at glide to riffle transitions below pools. Supports riparian vegetation establishment along the streambank. Does not include a constructed toe.	Provides channel margin roughness and complexity at transitions to point bars in upper portions of Reach 5. Supports riparian vegetation establishment along the streambank. Does not include a constructed toe.
Vegetated Wood and Brush Fascine – Type 1	Provides channel margin roughness and complexity along riffles and pools, and supports riparian vegetation growth along the streambank. Includes constructed toe to resist scour.	Provides channel margin roughness and complexity along riffles and pools, and supports riparian vegetation growth along the streambank. Includes constructed toe to resist scour.	Provides channel margin roughness and complexity along riffles, and supports riparian vegetation growth along the streambank. Includes constructed toe to resist scour.	Provides channel margin roughness and complexity along riffles and at outer meanders along pools in upper portions of Reach 5. Supports riparian vegetation growth along the streambank. Includes

Table 3-20. Streambank treatment applications by reach.

Streambank Treatment	Reach 2	Reach 3	Reach 4	Reach 5
				constructed toe to resist scour.
Vegetated Soil Lift Type 1	Supports bank shape and provides stable substrate so vegetation can establish on bank face. Located along riffles and shallower transitions to pools.	Supports bank shape and provides stable substrate so vegetation can establish on bank face. Located along riffles and shallower transitions to pools.	Supports bank shape and provides stable substrate so vegetation can establish on super-elevated bank face. Located along shallower transitions to pools.	Supports bank shape and provides stable substrate so vegetation can establish on bank face. Located along riffles and shallower transitions to pools.
Vegetated Soil Lift Type 2	Supports bank shape and provides stable substrate so vegetation can establish on bank face. Located along deeper areas where pools are present.	Supports bank shape and provides stable substrate so vegetation can establish on bank face. Located along deeper areas where pools are present.	Supports bank shape and provides stable substrate so vegetation can establish on super-elevated bank face. Located along outer meanders where pools are present.	Supports bank shape and provides stable substrate so vegetation can establish on bank face. Located along deeper areas where pools are present.
Large Wood Structure	Redirects flow away from banks and maintains pools. Located at low-radius outer meanders.	Redirects flow away from banks and maintains pools. Located at low-radius outer meanders.	Redirects flow away from banks and maintains pools. Located along outer meanders.	Redirects flow away from banks and maintains pools. Located at low-radius outer meanders.

3.7 Aquatic Habitat Design Criteria

This section describes aquatic habitat design criteria for stream reaches in the UBMC. As described in Section 1, the UBMC project area supports communities of resident westslope cutthroat trout, bull trout, and sculpin. Both westslope cutthroat trout and bull trout are Montana Species of Special Concern and bull trout is listed as a threatened species under the Federal Endangered Species Act. The portion of the Upper Blackfoot River below the UBMC project area is regarded as a recovery area for bull trout and was designated critical habitat for bull trout by the FWS in September 2010.

Aquatic habitat design criteria address the habitat requirements necessary to support populations of westslope cutthroat trout and bull trout. Aquatic habitat design criteria focus on creating complex aquatic environments and processes with features such as large wood, side channels, pools, undercut banks and substrates, and a variety of channel depths, gradients, velocities and structure. The desired future aquatic habitat condition includes restoring migratory, spawning, overwintering and rearing habitat to improve population resilience and connectivity with upstream reaches including Anaconda Creek and Beartrap Creek. The connected riparian floodplain corridor will be capable of providing nutrients for food web support, shade for cold water temperatures, and large wood recruitment for cover and pool development.

3.7.1 Aquatic Habitat Design Criteria

Design criteria for aquatic habitat are both numeric and qualitative. Numeric targets for the longitudinal distribution of aquatic habitat features are presented by reach. The design channels will have undulating bedforms typical of step-pool and riffle-pool stream types. Figure 3-2 includes a schematic illustrating the terminology related to longitudinal distribution of aquatic habitat features for a typical riffle-pool stream type. Design criteria are summarized in Table 3-21.

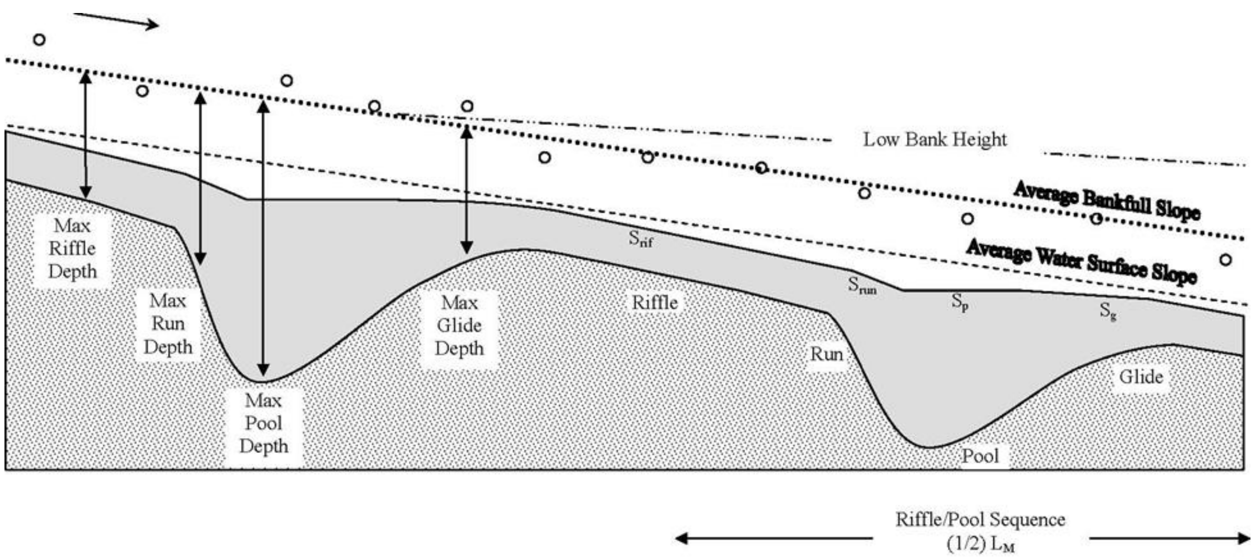


Figure 3-2. Schematic illustrating terminology for a riffle-pool bed morphology (Rosgen 1996).

Table 3-21. Design criteria for the distribution of aquatic habitat types by reach.

Reach	% Habitat Type[1]			
	Riffle	Run	Pool	Glide
Reach 2 Upper Beartrap Creek	50	10	30	10
Reach 3 Lower Beartrap Creek	35	15	35	15
Reach 4 Upper Blackfoot River	45	20	20	15
Reach 5 Middle Blackfoot River	35	15	25	25

[1] Design criteria can vary by ±10% to account for the range of natural variability

Aquatic habitat objectives for the UBMC project area include producing clean water consistent with supporting aquatic life, and creating complex aquatic habitat components such as depth, velocity, substrate, cover, and pools. Table 3-21 summarizes desired future conditions for aquatic habitat and focal fish species in the UBMC. Habitat requirements such as pool distribution and substrate size will be quantified during the final design phase of the project.

Table 3-22. Summary of desired future conditions for aquatic habitat and focal fish species in the project area.

Species	Habitat Potential	Target Life Stages	Habitat Requirements
Bull trout	Medium	Dispersion Juvenile Rearing Juvenile Overwintering	Pools Temperature Substrate size Interstitial space Cover Complexity
Resident Westslope cutthroat trout	Very High	Spawning Overwintering Juvenile Rearing	Pools Temperature Substrate size Interstitial space Cover Complexity
Migratory Westslope cutthroat trout	Very High	Spawning Juvenile Rearing	Pools Temperature Substrate size Interstitial space Cover Complexity

3.8 Vegetation Design Criteria

This section describes the vegetation design criteria for the UBMC. The vegetation design emphasizes creating a self-sustaining mosaic of riparian and wetland plant communities on a floodplain surface that is hydrologically connected to Mike Horse Creek and Beartrap Creek in the upper reaches and the Blackfoot River in the lower reaches. The design acknowledges that sediment transport and deposition, flood events, water storage, and nutrient regimes all play a role in plant community development. Each design plant community (cover type) represents a starting point for the development of a dynamic riparian or wetland system that has the ability to respond to interconnected factors at both the local and watershed scales. Local factors that influence vegetation community development and succession in the floodplain include groundwater, woody debris accumulation, sediment distribution, and accumulation of organic matter or litter. Landscape-scale factors that influence vegetation development include flood regimes, climate patterns, valley type, and surface water-groundwater interactions. These communities are not meant to be static, but are intended to develop and change over time in response to natural floodplain processes.

Design vegetation cover types integrate plant species composition with geomorphology and hydrology, and account for ecological processes that support plant community development over time. As part of the design, we recommend preserving existing wetland communities that are permanently saturated unless the deposition of contaminated tailings is inhibiting the ecological function of that wetland. Cover types described in this section provide a basis for planting and seeding plans, and include criteria for floodplain grading and substrate.

Cover types include: Natural Recruitment, Emergent Wetland, Shrub Wetland, Forested Wetland, Wetland Complex, Riparian Shrub, Transitional Riparian, Alder/Willow, Cottonwood/Aspen, Riparian Conifer, Upland Conifer, and Upland Slope. This section includes detailed descriptions of each of these cover types, restoration strategies for each cover type, and descriptions of revegetation treatments assigned to the cover types.

3.8.1 Vegetation Design Criteria

Design criteria for each vegetation cover type were developed based on the following physical factors that influence the development of plant communities:

- Location of the cover type longitudinally along the river;
- Geomorphic feature: the location of the cover type within the floodplain;
- Flood dynamic: the anticipated return interval for overbank flooding within the cover type;
- Estimated distance to groundwater;
- Elevation relative to the 1.5-year flow WSE;
- Soil texture: Range of soil textures that can support development of desired plant communities within the cover type; and
- Soil depth: depth of soil before alluvium is reached.

Table 3-23 provides ranges for each of these factors by cover type. The following discussion explains some of the rationale for vegetation design criteria within the project area. Vegetation cover types developed for this project may be changed during final design based on new information; for example, if a particular area is within a groundwater upwelling zone or at the toe of a slope producing groundwater, this may result in wetter cover types being located on higher ground relative to the channel.

Creating hydrologic connectivity between the channel and floodplain is necessary to support development of design vegetation cover types and their associated range of functions. Floodplain elevations shown in the preliminary design are intended to support hydrologic connectivity between the floodplain and channel. As a result, flows exceeding the 1.5-year return flow will deposit nutrients, sediment, and seeds on the floodplain, thereby creating and sustaining wetland and riparian vegetation. Floodplain topography that is part of this design also allows for surface connection to groundwater that transports additional nutrients to floodplain vegetation and develops complex food webs below ground (Brinson et al. 1995). Diverse topography will also support a variety of plant communities adapted to different microsites.

As with other natural floodplain processes, riparian soil development and related nutrient exchange also depends on the floodplain and channel being hydrologically connected. Riparian systems generally receive nutrients from allochthonous sources such as dead leaves and woody debris brought from upstream (Vannote et al. 1980). Topographic diversity in the form of oxbows, connected side channels, wetlands, and smaller depressions provides pathways and sinks for allochthonous inputs of organic matter and promotes soil development. A significant portion of organic matter and nutrients is also delivered to the floodplain during flood events (Tabacchi et al. 1998). A high proportion of fine sediment in floodplain soils consists of soil particles or mineral sediments originating from the stream channel where they were coated with organics (Gregory et al. 1991). Because these are the dominant nutrient and organic matter input pathways in floodplain systems, the vegetation design does not call for import of organic material or nutrients in the form of compost or commercial fertilizers for the riparian vegetation cover types. However, because it can take many years for organic matter to accumulate in wetlands through the decomposition of plant litter, it may be necessary to amend soils within off channel wetland cover types.

The appropriate substrate to support vegetation development includes cobble, gravel, and sand (alluvium) on exposed depositional and colonizing surfaces, and sandy loam to finer textured soils on higher elevation floodplain surfaces and within wetlands. Soil depth should be 6 to 12 inches within most cover types, which reflects the typically shallow soils found on western Montana alluvial floodplains, where most fine-textured soil that accumulates on alluvium is made up of sediment trapped by established woody vegetation. The organic component of these soils is typically low (1.5 to 2.5 percent) because most organics are derived from either litter that has accumulated over a relatively short time frame or organics that have moved in through the water column and coated soil particles (as described above). Deeper vegetative growth media will be placed in wetland cover types as these systems typically have more developed soil profiles. In addition, anaerobic conditions within these constantly-saturated features result in the accumulation of soil organic matter because the organics do not decompose rapidly. Therefore, organic matter content in soils of design wetland cover types will trend toward 5 percent or greater. Based on these concepts, cover types have been assigned according to criteria in Table 3-23, and the preliminary distribution of cover types is shown in Figures 3-3, 3-4, 3-5 and 3-6.

Table 3-23. Design criteria for cover types within the UBMC project area.

Floodplain Cover Type	Project Reaches	Geomorphic Design Feature(s)	Geomorphic Disturbance	Flood Return Interval	Elevation Relative to 1.5-Year WSE (feet)	Soil Texture	Vegetative Backfill (inches to alluvium)
Natural Recruitment	3, 4, 5	Non-vegetated portion of point bars	High	< 1 year	- 0.5 to 0	Sand, fine to coarse gravel or cobble, (alluvium)	0
Emergent Wetland	3, 4, 5	Passive margins along channel; wetlands, and backwater areas	Low	< 1 year	-2.0 to -1.0	Organic and loam (vegetative backfill) underlain by sand/gravel	24
Shrub Wetland	5, 6	Wetlands	Low	< 1 year	-2.0 to 0.5	Organic and loam (vegetative backfill) underlain by sand/gravel	24
Wetland Complex	5, 6	Wetlands	Low	< 1 year	-2.0 to -1.0	Organic and loam (vegetative backfill) underlain by sand/gravel	24
Forested Wetland	5	Margins of emergent and shrub wetlands down gradient of forested upland	Low	1 to 2 years	-2.0 to 0	Organic and loam (vegetative backfill) underlain by sand/gravel	24
Riparian Shrub	3, 4, 5	Bankfull floodplain	Medium	1 to 5 years	0 to 0.5	Silt loam to sandy loam (vegetative backfill) overlying alluvium	12

Table 3-23. Design criteria for cover types within the UBMC project area.

Floodplain Cover Type	Project Reaches	Geomorphic Design Feature(s)	Geomorphic Disturbance	Flood Return Interval	Elevation Relative to 1.5-Year WSE (feet)	Soil Texture	Vegetative Backfill (inches to alluvium)
Willow/ Alder	1, 2, 3	Bankfull floodplain	Medium	1 to 5 years	0 to 0.5	Silt loam to sandy loam (vegetative backfill) overlying alluvium	12
Transitional Riparian	1, 2, 3	Bankfull floodplain; low terrace	Medium	1 to 5 years	0.5 to 2	Silt loam to sandy loam (vegetative backfill) overlying alluvium	12
Cottonwood/ Aspen	3, 4, 5	Bankfull floodplain; Low terrace	Medium	1 to 5 years	0.5 to 2.0	Silt loam to sandy loam (vegetative backfill) overlying alluvium	12
Riparian Conifer	3, 4, 5	Bankfull floodplain; High terrace	Low	1 to 10 years	0.5 to 2.0	Silt loam to sandy loam (vegetative backfill)	12
Upland Conifer	1, 2, 3, 4, 5	Slope transitions to higher terraces; upland inclusions	Low	10+ years	2.0 +	Silt loam to sandy loam (vegetative backfill)	12
Upland Slope	1, 2, 3, 4, 5	Unvegetated side slopes	Low	NA	4.0 +	Silt loam to sandy loam	12

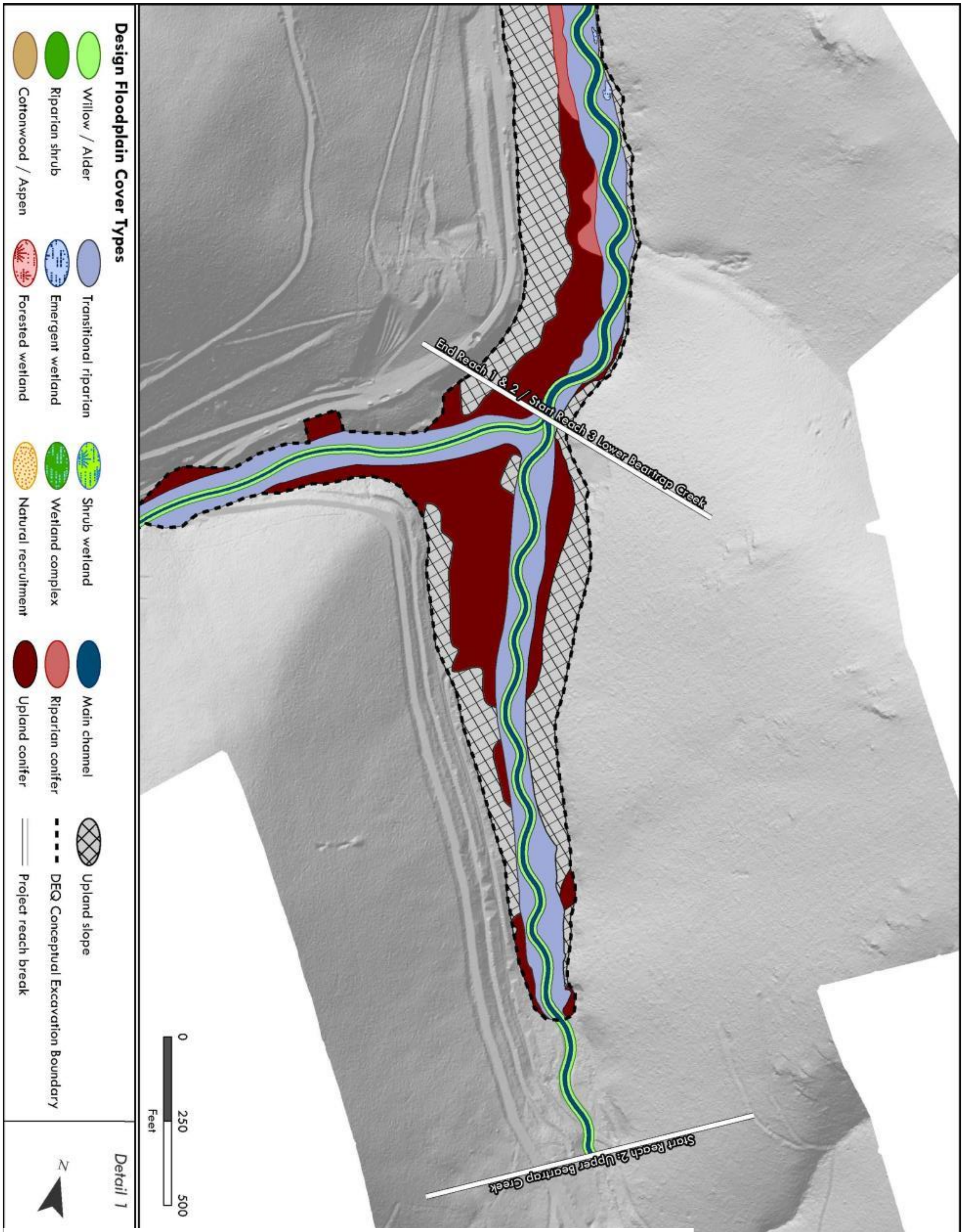


Figure 3-3. Cover type distribution in Reaches 1, 2 and 3.

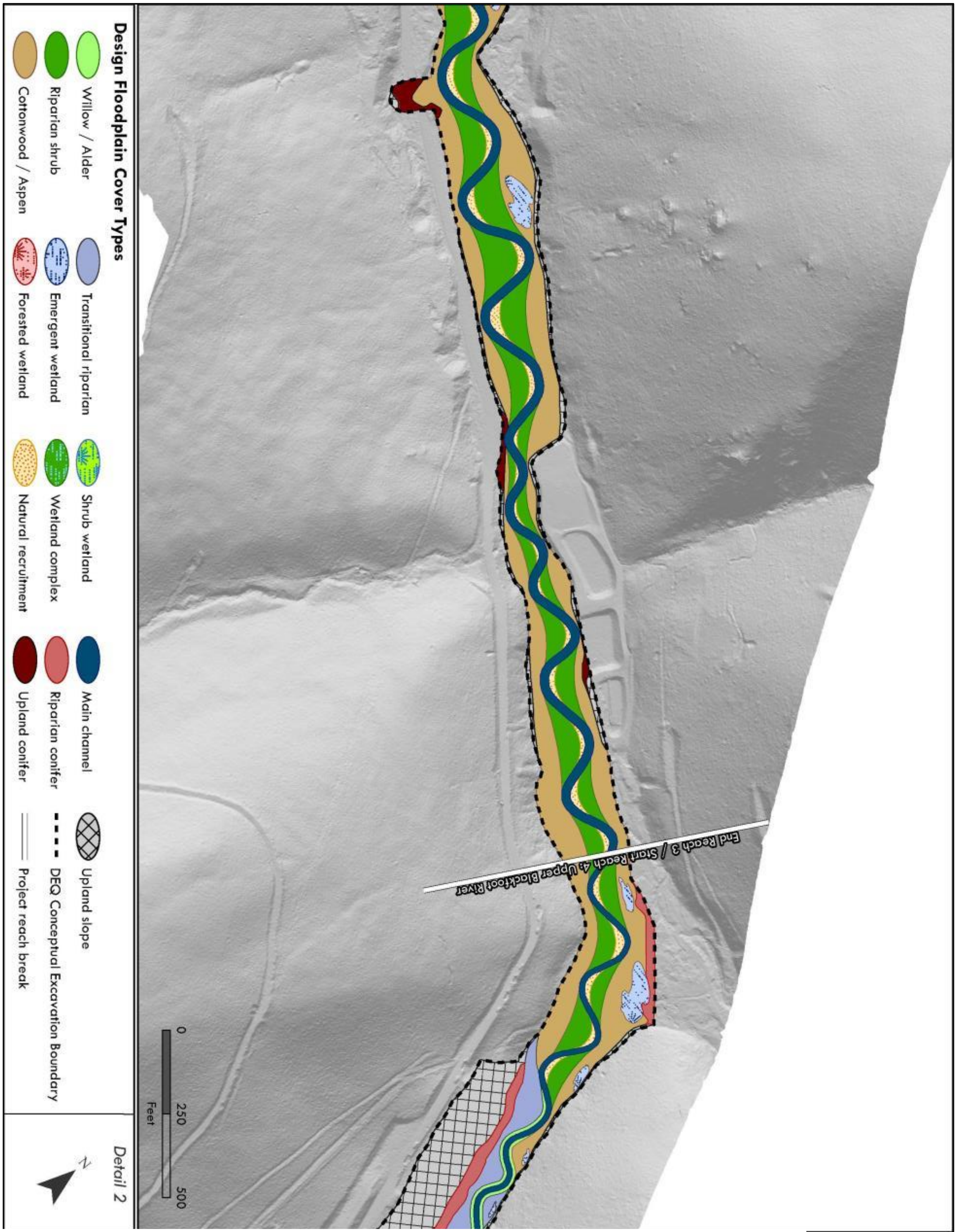


Figure 3-4. Cover type distribution in Reaches 3 and 4.

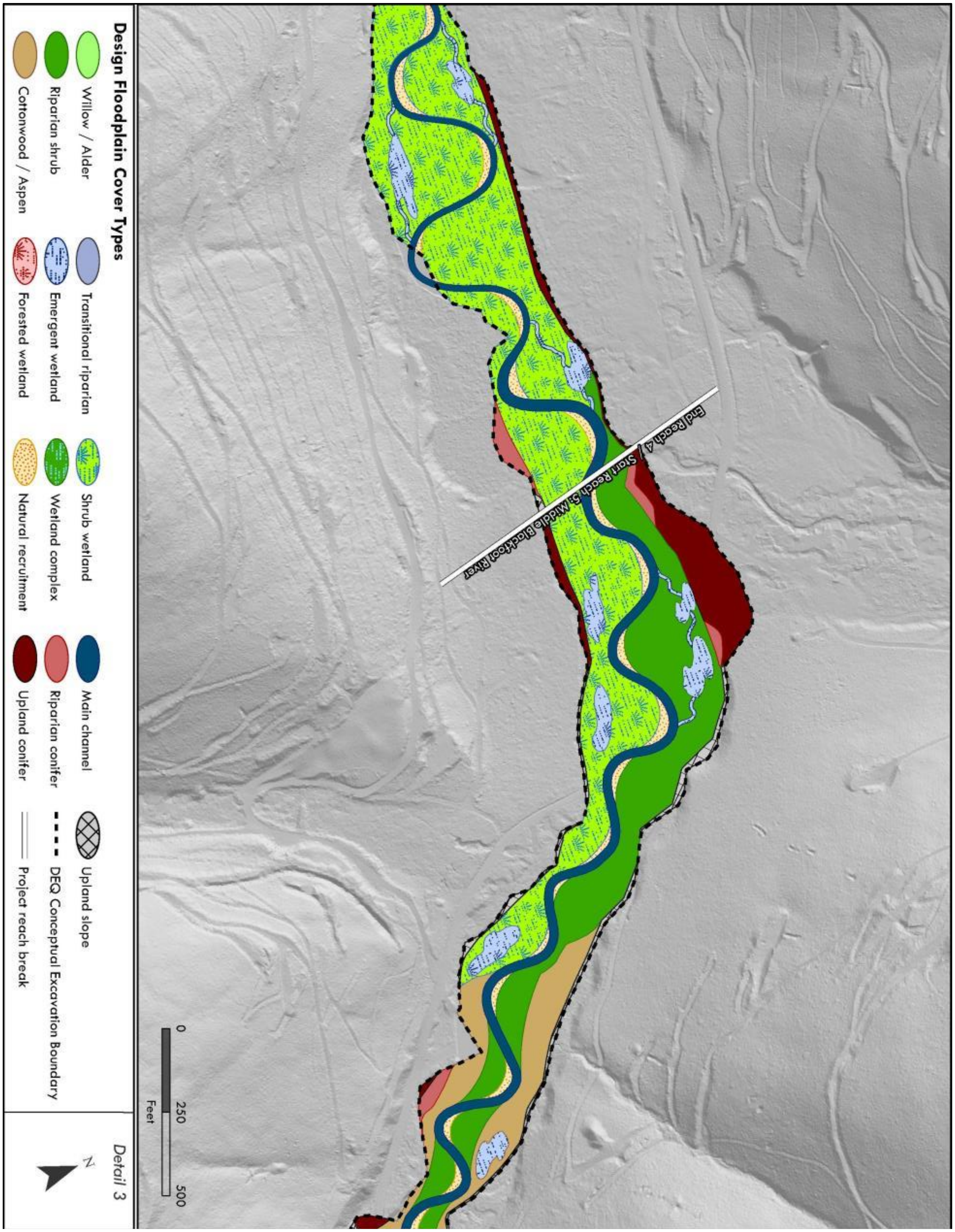


Figure 3-5. Cover type distribution in Reaches 4 and 5.

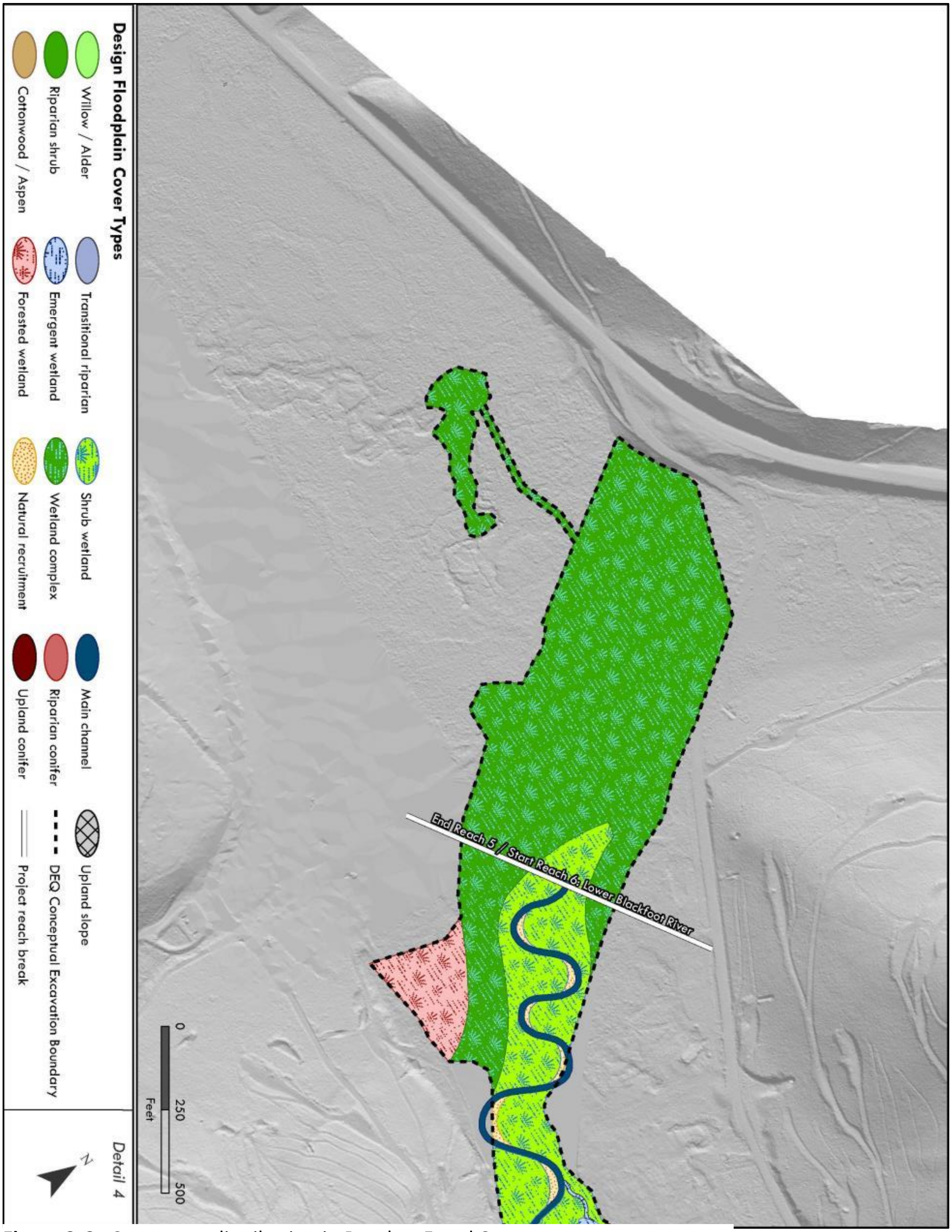


Figure 3-6. Cover type distribution in Reaches 5 and 6.

3.8.2 Vegetation Cover Type Descriptions

Natural Recruitment

Within portions of Reaches 3, 4, and 5, a natural recruitment zone is identified (Figures 3-3, 3-4, 3-5 and 3-6). These areas would be constructed so the final graded surface is composed of alluvial sand, gravel and cobble with microtopography and wood incorporated into the floodplain surface. Elevations within this zone would be at or below the bankfull floodplain elevation. The natural recruitment zone would be located on inside meanders where dominant floodplain sediment transport processes are depositional. Riparian tree and shrub species such as cottonwoods and willows can establish from seed on these sand, gravel and cobble surfaces. In these areas, moisture is present during late spring and early summer, coincident with the declining limb of the hydrograph. Because native riparian tree and shrub seed sources are present within the UBMC project area, this zone is intended to take advantage of natural processes that support natural tree and shrub recruitment in areas where risk of either erosion or channel avulsion is low. This zone represents areas that will initially develop as cottonwood or willow stands, and may ultimately shift to conifer dominance as the floodplain aggrades due to natural sedimentation. Table 3-24 summarizes revegetation criteria and treatments for the Natural Recruitment cover type.

Table 3-24. Natural Recruitment cover type criteria and revegetation treatments.

Treatment	Criteria/Description
Grading	-0.5 to 0 feet relative to 1.5-year water surface elevation
Soil texture	Sand, fine to coarse gravel or cobble (alluvium)
Vegetative backfill depth	No vegetative backfill
Microtopography	Partially buried woody debris
Containerized planting: Shrubs and trees	None
Containerized planting: Herbaceous plugs	None
Seeding	None

Emergent Wetland

The Emergent Wetland cover type will occur primarily within off-channel wetland features and connected wetland complexes throughout the floodplain in Reaches 3, 4 and 5. This cover type will consist of herbaceous wetland plants such as sedges (*Carex* spp.), rushes (*Juncus* spp.), wetland grasses (*Glyceria* spp. and *Calamagrostis* spp.), and wetland forbs. These areas have deeper soils that are saturated or inundated throughout much of the growing season. The

Emergent Wetland cover type will support several ecological functions including flood water retention and energy dissipation, sediment storage, primary production, aquatic and terrestrial habitat, aquifer recharge, and nutrient cycling. The future condition of these areas will be a highly functioning wetland with a diverse, native plant community.

Revegetation strategies within the Emergent Wetland cover type include constructing topographic depressions with low-gradient slopes that are connected to groundwater during most of the growing season. These areas would receive deep vegetative cover soil with approximately 5% organic content. These areas would be seeded and planted with containerized wetland plugs. Table 3-25 summarizes revegetation criteria and treatments for the Emergent Wetland cover type.

Table 3-25. Emergent Wetland cover type criteria and revegetation treatments.

Treatment	Criteria/Description
Grading	-2.0 to -1.0 feet relative to 1.5-year water surface elevation with maximum 10:1 slopes.
Soil texture	Loam to clay loam (vegetative backfill)
Vegetative backfill depth	24 inches
Microtopography	Partially buried woody debris
Containerized planting: Herbaceous plugs	Herbaceous plugs installed according to appropriate hydrologic zones
Seeding	Native seed mix including grasses, sedges, rushers and forbs

Shrub Wetland

The Shrub Wetland cover type will be similar to existing Shrub Wetlands in Reaches 5 and 6 that have developed in response to high groundwater and beaver impoundments. This cover type will occur as off channel wetlands. Plant communities in this cover type include a shrub overstory of willows and birch (*Betula* species), with a diverse understory comprised of various sedges, rushes, wetland grasses and forbs. Soils within this cover type are deep, have relatively high organic content, and are expected to remain saturated or inundated throughout much of the growing season. The Shrub Wetland cover type will contribute to primary production, nutrient cycling, and aquatic and terrestrial habitat among other desired ecological functions.

The Shrub Wetland cover type would be located in areas within the bankfull floodplain where groundwater is close to the surface. These areas would receive deep vegetative cover soil with approximately 5% organic content. Shrub Wetlands would be seeded and planted with containerized shrub and wetland plugs. Table 3-26 summarizes revegetation criteria and treatments for the Shrub Wetland cover type.

Table 3-26. Shrub Wetland cover type criteria and revegetation treatments.	
Treatment	**Criteria/Description**
Grading	-2.0 to 0.5 feet relative to 1.5-year WSE
Soil texture	Loam to clay loam (vegetative backfill)
Vegetative backfill depth	24 inches
Microtopography	Partially buried woody debris
Containerized planting: Herbaceous plugs	Shrubs and trees will be installed in all areas of this cover type
Browse protection	Individual plant protectors or exclosures
Seeding	Native seed mix including grasses, sedges, rushes and forbs

Forested Wetland

The Forested Wetland cover type is similar to existing Forested Emergent and Forested Shrub Wetland communities in Reaches 5 and 6 and its purpose is to restore Forested Wetland communities where they occurred historically. Plant communities in this ecosystem will include an overstory of conifers, with understory communities consisting of willow and alder species. The herbaceous vegetation community will include sedges, rushes and wetland grasses. Soils within this cover type are deep loam, and are saturated throughout the growing season. The Forested Wetland cover type will contribute to nutrient cycling and terrestrial habitat, in addition to supporting other wetland functions.

Revegetation strategies within the Forested Wetland cover type include constructing topographic depressions with low-gradient slopes that are connected to groundwater during most of the growing season. Other non-depressional areas within the bankfull floodplain would also support this cover type where groundwater is close to the surface. These areas would receive deep vegetative cover soil with approximately 5% organic content. Forested Wetlands would be seeded and planted with containerized trees, shrubs and wetland plugs. Table 3-27 summarizes revegetation criteria and treatments for the Forested Wetland cover type.

Table 3-27. Forested Wetland cover type criteria and revegetation treatments.	
Treatment	**Criteria/Description**
Grading	-2.0 to 0 feet relative to 2-year WSE
Soil texture	Loam to clay loam (vegetative backfill)
Vegetative backfill depth	24 inches
Microtopography	Partially buried woody debris

Table 3-27. Forested Wetland cover type criteria and revegetation treatments.	
Treatment	**Criteria/Description**
Containerized planting: Shrubs and Trees	Shrubs and trees will be installed in all areas of this cover type
Browse Protection	individual protectors
Seeding	Native seed mix including grasses, sedges, rushes and forbs

Wetland Complex

This cover type occurs in Reach 6 within an existing wetland complex that includes emergent, shrub and forested wetland communities. The Wetland Complex cover type would be located at elevations ranging from -2.0 to 0.5 relative to the 1.5 year return flow. This cover type's broad definition reflects the need to restore a functioning wetland complex in an area where tailings removal extents are still being determined. Plant communities in this cover type would include a mosaic of emergent, shrub and forest wetland cover types described above. Soils within this cover type are deep, organic and saturated or inundated throughout much of the growing season. Some areas adjacent to fens include peat soils. The Wetland Complex cover type will contribute to primary production, nutrient cycling, and aquatic and terrestrial habitat among other desired ecological functions.

Revegetation strategies for the Wetland Complex cover type include reconstructing marsh topography with sufficient structure to support beaver impoundments. Wetland soil (including peat) and vegetation from adjacent remediation areas may be salvaged and replaced within the Wetland Complex. In general, these areas would receive deep vegetative cover soil with approximately 5% organic content or greater. This area would be seeded and planted with containerized trees, shrubs and wetland plugs. Table 3-6 summarizes revegetation criteria and treatments for the Wetland Complex cover type.

Table 3-28. Wetland Complex cover type criteria and revegetation treatments.	
Treatment	**Criteria/Description**
Grading	-2.0 to 0.5 feet relative to 1.5-year WSE
Soil texture	Loam to clay loam (vegetative backfill)
Vegetative backfill depth	24 inches
Microtopography	Partially buried woody debris and other surface logs to provide anchors for beaver dam construction
Browse protection	Individual protectors

Table 3-28. Wetland Complex cover type criteria and revegetation treatments.	
Treatment	**Criteria/Description**
Seeding	Native seed mix including grasses, sedges, rushes and forbs

Willow/Alder and Riparian Shrub

These cover types occur immediately adjacent to streambanks, up to approximately 0.5 ft above the elevation of the bankfull floodplain (1.5 year return flow water surface elevation). These cover types are combined here because they are both located adjacent to the stream channel, and they only differ in species composition and proportion. The Willow/Alder cover type is primarily an alder community and is associated with Mike Horse and Beartrap Creeks in Reach 1, Reach 2 and the upper portion of Reach 3. The dominant plant species within this cover type is sitka alder with a minor component of various willows, along with an understory dominated by grasses and forbs. The Riparian Shrub zone, dominated by a willow community, is present in Reaches 3 and 4, and represents an early successional phase of the tree-dominated cover types. The Riparian Shrub cover type would include willows, sitka alder and cottonwoods. The understory would include sedges, grasses, and forbs.

Within this community, roots of planted shrubs would integrate with structural materials (rock, wood, or fabric-wrapped soil) to support streambanks and function as a vegetative control on channel morphology. In middle reaches, structural controls would include a combination of native rock and embedded wood, and in downstream (lower gradient, smaller substrate) reaches, structural controls would be mainly wood and fabric-wrapped banks. Shrubs that establish along streambanks would also provide overhanging bank cover, shade and food web inputs into the stream channels.

Revegetation strategies within the Willow/Alder and Riparian Shrub cover types include planting containerized trees and shrubs, installing vegetative cuttings within fabric-wrapped banks (vegetated soil lifts), seeding and incorporation of wood and varied substrate. Table 3-29 summarizes revegetation criteria and treatments for the Willow/Alder and Riparian Shrub cover types.

Table 3-29. Willow/Alder and Riparian Shrub cover type criteria and revegetation treatments.	
Treatment	**Criteria/Description**
Grading	-0.5 to 1.0 feet relative to 1.5-year water surface elevation
Soil texture	Silt loam to sandy loam
Vegetative backfill depth	6 to 12 inches

Table 3-29. Willow/Alder and Riparian Shrub cover type criteria and revegetation treatments.

Treatment	Criteria/Description
Microtopography	Partially buried large and coarse woody debris scattered throughout floodplain
Containerized planting	Shrubs installed throughout this cover type
Browse protection	Exclosures around groups of plantings; individual protectors in areas where exclosures are not feasible
Seeding	Native seed mix; primarily grasses and forbs

Transitional Riparian

The Transitional Riparian cover type is located on sloped areas of the floodplain between the river channel and the remaining conifer forest in Reaches 1, 2 and 3 at elevations ranging from at or below the bankfull floodplain to approximately two feet above bankfull. This cover type represents a transitional vegetation community with a diverse mix of trees and shrubs including conifers, cottonwood, willows, alder and other more mesic shrubs. Species that tolerate wetter conditions will be planted closer to the channel while more mesic species will be planted higher on the slope. This cover type differs from other riparian cover types in that it occupies a transitional slope between the channel and upland as opposed to being located on terrace features.

The revegetation strategy for the Transitional Riparian cover type includes grading and substrate placement associated with floodplain construction, installation of large and coarse woody debris (microtopography) to create niches and microsites for vegetation development and add organic matter to the soil, installation of containerized plant material to promote the establishment of the vegetation community and provide a long-term seed source, installation of browse protection to protect containerized plants from ungulate and beaver browse, and seeding. Table 3-30 summarizes revegetation criteria and treatments for the Transitional Riparian cover type.

Table 3-30. Transitional Riparian cover type criteria and revegetation treatments.

Treatment	Criteria/Description
Grading	Areas above the 1.5-year water surface elevation
Soil texture	Silt loam to sandy loam
Vegetative backfill depth	12 inches
Microtopography	Partially buried large and coarse woody debris scattered throughout floodplain

Table 3-30. Transitional Riparian cover type criteria and revegetation treatments.	
Treatment	**Criteria/Description**
Containerized planting	Trees and shrubs installed in all areas of this cover type
Browse protection	Exclosures around groups of plantings; individual protectors in areas where exclosures are not feasible
Seeding	Native seed mix; primarily grasses and forbs

Cottonwood/Aspen

The Cottonwood/Aspen cover type is located at elevations ranging from at or below the bankfull floodplain to the low terrace (approximately 0.5 ft above bankfull). This zone is present in Reaches 4, 5 and 6 and represents an early successional phase of conifer plant communities. Within The Cottonwood/Aspen cover type, a mixture of cottonwoods, aspens and riparian shrubs will occupy the floodplain surface and function to trap sediment (thereby building the floodplain), provide roughness to slow velocities during flood flows, and stabilize floodplain soils. Within this cover type, large wood and microtopography would be incorporated as part of floodplain construction. Over time, relatively short-lived cottonwoods and aspens would be sources for large wood inputs into the stream, and would help sustain aquatic habitat complexity. This cover type is located at similar elevations to the Riparian Conifer cover type, but is closer to the stream channel and therefore includes species better adapted to geomorphic disturbance. This cover type would eventually transition into the Riparian Conifer cover type as conifers from the adjacent upland begin to move into this zone.

Tree and shrub species that may be planted include black cottonwood, quaking aspen, various willows, alder species, and other near-bank riparian shrubs that would be selected as part of later design phases. Conifer species such as lodgepole pine and Douglas-fir may also be included as part of this community.

Revegetation strategies within the Cottonwood/Aspen cover type include planting containerized trees and shrubs, seeding, and incorporating wood and varied substrate. Table 3-31 summarizes revegetation criteria and treatments for the Cottonwood/Aspen cover type.

Table 3-31. Cottonwood/Aspen cover type criteria and revegetation treatments.	
Treatment	**Criteria/Description**
Grading	0.5 to 2.0 feet relative to 1.5-year WSE
Soil texture	Silt loam to sandy loam
Vegetative backfill depth	6 to 12 inches

Table 3-31. Cottonwood/Aspen cover type criteria and revegetation treatments.	
Treatment	**Criteria/Description**
Microtopography	Partially buried large and coarse woody debris scattered throughout floodplain
Containerized planting	Shrubs and trees
Browse protection	Exclosures around groups of plantings; individual protectors in areas where exclosures are not feasible
Seeding	Native seed, primarily grasses and forbs

Riparian Conifer

The Riparian Conifer cover type occurs on low terraces, which range from approximately 0.5 ft above the bankfull floodplain elevation to approximately the toe of slope. Riparian conifers such as spruce (*Picea* spp.), subalpine fir and Douglas-fir represent the long-term potential natural community for most riparian areas within the UBMC project area. As noted above, shrubs, cottonwoods and aspen would naturally colonize near-bank areas either before or alongside conifers, so short-term revegetation goals focus on those species near the streambanks and on the bankfull floodplain. However, on drier terraces, natural recruitment processes would favor conifers, so initial revegetation would include a conifer planting component on terrace features.

The Riparian Conifer cover type is present in Reaches 3 through 5 and represents a moderate to late successional phase of tree-dominated conifer habitat types. Within this community, a mixture of conifers and shrubs would occupy the terrace surface and function to stabilize soils (limiting erosion potential), provide habitat for terrestrial wildlife and birds that use riparian corridors, and provide long-term large wood inputs onto the floodplain and into the stream, sustaining riparian and aquatic habitat complexity. Within this cover type, large wood and microtopography would be incorporated as part of floodplain construction.

Tree and shrub species that may be planted include lodgepole pine, Douglas-fir, quaking aspen, chokecherry, western serviceberry, Rocky Mountain maple, and other species that would be selected as part of later design phases. Later successional species like subalpine fir and spruce may not be planted directly; rather, terrace and floodplain grading would include incorporating microsites that would allow these species to recruit naturally from readily available on-site seed sources adjacent to the stream channels.

Within the Riparian Conifer vegetation cover type, the primary revegetation technique would be planting of containerized nursery stock, and these would be protected from browse using either exclosures or individual plant protectors. The constructed floodplain surface would incorporate buried wood and microtopography to create microsites, and areas would be seeded with grasses and forbs. Table 3-32 summarizes revegetation criteria and treatments for the Riparian Conifer cover type.

Table 3-32. Riparian Conifer cover type criteria and revegetation treatments.

Treatment	**Criteria/Description**
Grading	0.5 to 2.0 feet relative to 1.5-year WSE
Soil texture	Silt loam to sandy loam
Vegetative backfill depth	6 to 12 inches
Microtopography	Partially buried large and coarse woody debris throughout floodplain
Containerized planting	Shrubs and trees
Browse protection	Exclosures around groups of plantings; individual protectors in areas where exclosures are not feasible
Seeding	Native seed mix including grasses and forbs

Upland Slope

This vegetation cover type is intended for steeper slopes in Reaches 2 and 3 that exceed 2.5H to 1V in steepness. Plant species mixes are similar to the Upland Conifer cover type, but species vary depending on whether slopes are east facing or west facing. Erosion control measures such as placing talus, contour logs and other techniques will be applied along with seeding and planting in order to stabilize soils and establish herbaceous cover. This cover type will include two separate plant mixes, one for east facing slopes and one for west facing slopes. East facing slopes will consist of species adapted to moist, shadier conditions while south facing plant species are adapted to dry, sunnier conditions. Table 3-12 summarizes revegetation criteria and treatments for the Upland Slope cover type.

Table 3-33. Upland slope cover type criteria and revegetation treatments.

Treatment	**Criteria/Description**
Grading	Upper slopes that exceed 2.5H to 1V
Soil Texture	Sandy loam
Vegetative Backfill Depth	6 inches
Microtopography	Large and coarse woody debris scattered across slope to maximize erosion control function
Containerized planting	Trees and shrubs

Table 3-33. Upland slope cover type criteria and revegetation treatments.	
Treatment	**Criteria/Description**
Browse protection	Individual plant protectors
Seeding	Native grass and forb species

4 Preliminary Restoration Design by Reach

This section includes descriptions of restoration designs for each reach. Because remediation designs have been developed at a higher level of detail in some reaches than others, different reaches are addressed with varying levels of detail in this section and in the plan set (Appendix A). For example, tailings removal extents are still being developed for Reach 1 Mike Horse Creek and Reach 6 Lower Blackfoot River. In contrast, tailings removal extents have been established at a preliminary level of detail for Reaches 2, 3, 4 and 5. Therefore, restoration grading has also been developed to a higher level of detail in Reaches 2, 3, 4 and 5. Restoration design will continue to be coordinated with the remedial design effort as removal extents are refined in Reach 1 and Reach 6.

4.1 Reach 1 Mike Horse Creek

4.1.1 Introduction

Because the excavation extents are still being refined, this section describes a conceptual restoration approach for Reach 1. The conceptual design for Reach 1 is shown in Appendix A, Sheet 5.0. For purposes of describing design concepts, Reach 1 has been divided into three sub-reaches: 1A; 1B; and 1C. As described in Section 1, restoration objectives for Reach 1 emphasize producing clean water, reducing sediment, modifying road crossings to support fish passage, and relocating roads and other infrastructure out of the riparian area.

4.1.2 Restoration Strategies in Reach 1A

Reach 1A begins at the upstream extent of the project area along Mike Horse Creek, at a concrete coffer dam structure that currently functions as an intake for clean water being piped around the contaminated upper reach of Mike Horse Creek. The downstream end of Reach 1A is marked by a bedrock outcrop which functions as a channel grade control. Remedial concepts for Reach 1A focus on separating surface water from groundwater using a clay liner, because groundwater becomes contaminated as it comes in contact with old mine works in this area. Therefore, a restored stream, floodplain and riparian area in this reach will need to be constructed on top of the clay layer to maintain this separation.

The restoration concept for Reach 1A addresses objectives for Reach 1 by creating three zones whose purpose is to limit sedimentation into Mike Horse Creek from adjacent mineralized hillslopes. These three zones are illustrated in concept in Figure 4-1 and in Appendix A, Sheet 5.0. Immediately adjacent to Mike Horse Creek, a floodplain zone would support a riparian buffer that would include willows, alders and an understory of riparian and wetland herbaceous plants. This riparian buffer would function as a filter strip and would be capable of attenuating metals to some degree while trapping and storing fine sediments that originate from adjacent hillslopes. Outside the riparian buffer, an intensive slope treatment zone would include treatments aimed at providing slope stability and vegetative cover. Potential treatments range from geotechnical slope stabilization using synthetic materials such as geo-cells, to bioengineering treatments using biodegradable contour wattles combined with fabric, compost and possibly cover soil. This intensive slope treatment zone would occupy the area between an access road and the riparian buffer, and would be approximately 50 feet to 100 feet wide (slope length). The objective in this zone would be for vegetation to establish and provide slope stability within one or two growing seasons. Above the intensive slope treatment zone, there is opportunity for additional slope treatment. Because this zone is further from Mike Horse Creek, less intensive treatments using native materials from onsite could be applied, where revegetation would occur over a longer time frame and be driven by natural processes rather than by the engineering approaches used in the intensive slope treatment zone. Within the additional slope treatment zone, potential treatments include constructing talus slopes, importing cover soil from the Section 35 repository, placing beetle killed trees from onsite along contours, collecting and spreading litter and duff from adjacent forested areas to provide seed sources and mycorrhizae adapted to the site, and spreading smaller brush to provide a long-term source of organic carbon to naturally build soil over time. Concepts and illustrations are preliminary and actual designs will need to be coordinated with the integrated remediation/restoration design process for this area.

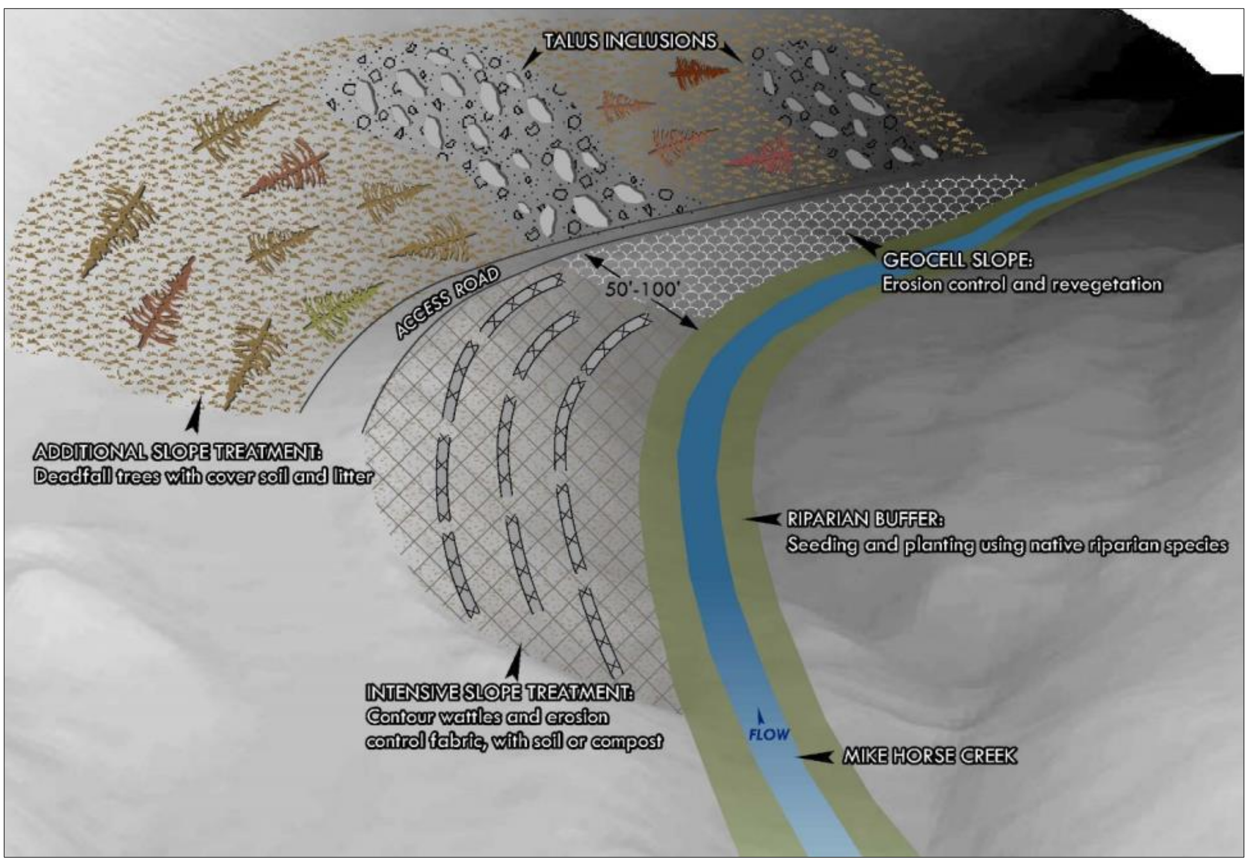


Figure 4-1. Restoration concepts for upper Mike Horse Creek, Reach 1A.

4.1.3 Restoration Strategies in Reach 1B

Reach 1B is located between the bedrock control that marks the downstream end of Reach 1A and the USFS boundary (Appendix A, Sheet 5.0). Within this subreach, Mike Horse Creek is confined against the south side of the narrow valley and flows in a rock-armored channel, contacting bedrock in several locations. This area includes significant infrastructure, including a waste pile and settling pond, and decisions are still being made about how to address this infrastructure. Because restoration objectives include relocating roads and removing unnecessary infrastructure in Reach 1, one alternative in Reach 1B is to relocate the access road higher on the adjacent slope, and remove or reconfigure infrastructure such that the valley bottom width can be increased. This would provide Mike Horse Creek access to a slightly wider floodplain and make it possible to develop a riparian buffer similar to the buffer described for Reach 1A. If infrastructure within this subreach is not removed or relocated, restoration actions would likely be limited to enhancing riparian vegetation along the existing Mike Horse Creek alignment.

4.1.4 Restoration Strategies in Reach 1C

Reach 1C extends from the USFS boundary to the Mike Horse Creek confluence with Reach 2 Upper Beartrap Creek (Appendix A, Sheet 5.0). The restoration concept in Reach 1C includes developing a moderately entrenched and confined stream channel with step-pool morphology developed with a narrow, well-vegetated riparian zone (A2 stream type). Bedforms would consist primarily of step-pool features formed by large roughness elements including large wood, alluvium and boulders.

Vegetation cover types in Reach 1C would also be similar to Reach 2 and the upper portion of Reach 3, and would be assigned when a channel alignment and grading plan have been developed. Likely cover types include Willow/Alder and Transitional Riparian (Section 3.8). The Willow/Alder cover type would occupy low elevation areas within the bankfull floodplain adjacent to the channel, and would function as a riparian buffer. The Transitional Riparian cover type would function as a transition zone between the shrub-dominated riparian area and the adjacent conifer slope.

Sequencing of restoration in Reach 1C would need to be coordinated with remediation components that would include a settling pond above a haul road crossing. It is likely restoration work in the vicinity of the haul road crossing would be completed after work in Reach 2 has been substantially completed. A more detailed description of sequencing and integration with remediation is included in Section 5 of this report.

4.2 Reach 2 Upper Beartrap Creek

4.2.1 Introduction

Reach 2 extends from the upper end of the existing Mike Horse Dam impoundment to the confluence with Reach 1 Mike Horse Creek (Appendix A, Sheet 3.1). Preliminary grading, typical stream alignment, structure details, and planting/seeding plans are shown in Appendix A. Section 3 describes how design criteria are applied to Reach 2.

4.2.2 Restoration Strategies

The preliminary restoration plan for Reach 2 proposes a moderately steep channel developed within a narrow, well-vegetated floodplain corridor. Restoration strategies will focus on constructing a low sinuosity, step-pool, small boulder dominated B stream type with interspersed riffles and rapids (B2a and B2 stream types). Due to the lower gradient of Reach 2 compared to Reach 1 Mike Horse Creek, and anecdotal information that indicates Upper Beartrap Creek once supported westslope cutthroat trout, restoring fluvial connectivity and high quality aquatic habitat conditions are a priority in Reach 2. Bankfull channel width will range from 9.7 feet to 11.5 feet with an average depths of 0.9 feet for riffles and maximum depth of 2.8 feet for pool channel units (Appendix A, Sheet 13.0). The average slope in Reach 2 will be approximately 3.8%, which represents a high energy fluvial environment that will necessitate channel bed structures to maintain vertical bed stability and floodplain connectivity. Because the estimated mobile particle size in the active channel for the Q25 and Q50 recurrence interval floods range from 460 mm (18-inch) to 534 mm (21-inch), channel bed features will consist of constructed riffles and step pool structures built with wood, coarse cobble, and small boulder particle sizes. A typical structure sequence for Reach 2 is provided in Appendix A on Sheet 6.2. As shown, streambank treatments will be comprised of large wood structures, vegetated wood and brush fascines, and vegetated soil lifts. Floodplain treatments will include swales and microtopographic grading. Typical streambank, channel, and floodplain treatment details are included in Appendix A (Sheets 14.0-14.8).

The revegetation design for Reach 2 includes four cover types: Willow/Alder cover type, Transitional Riparian cover type, Upland Conifer cover type, and Upland Slope cover type. These vegetation cover types are described in more detail in Section 3.8 and illustrated in Sheet 15.0 in Appendix A. The Willow/Alder cover type would occupy low elevation areas within the bankfull floodplain adjacent to the channel. The Transitional Riparian cover type would occupy areas outside and upgradient of the Willow/Alder cover type, and would function as a transition zone between the shrub-dominated riparian zone and adjacent conifer forest. The Upland Conifer cover type would occupy higher elevation areas with a slope of less than 2.5:1 within the slope transition between the floodplain and existing upland vegetation. The Upland Slope cover type would occupy a zone at higher elevation areas where the slope is steeper than 2.5:1. Within Reach 2, the Upland Slope cover type zone is more extensive than in other reaches because valley slopes currently buried under tailings would likely support upland vegetation once tailings are removed. Figure 4-2 provides a typical view of existing ground with approximate extents of contamination, estimated conditions immediately after restoration has been completed, and a desired future condition for the site once it has had time to mature.

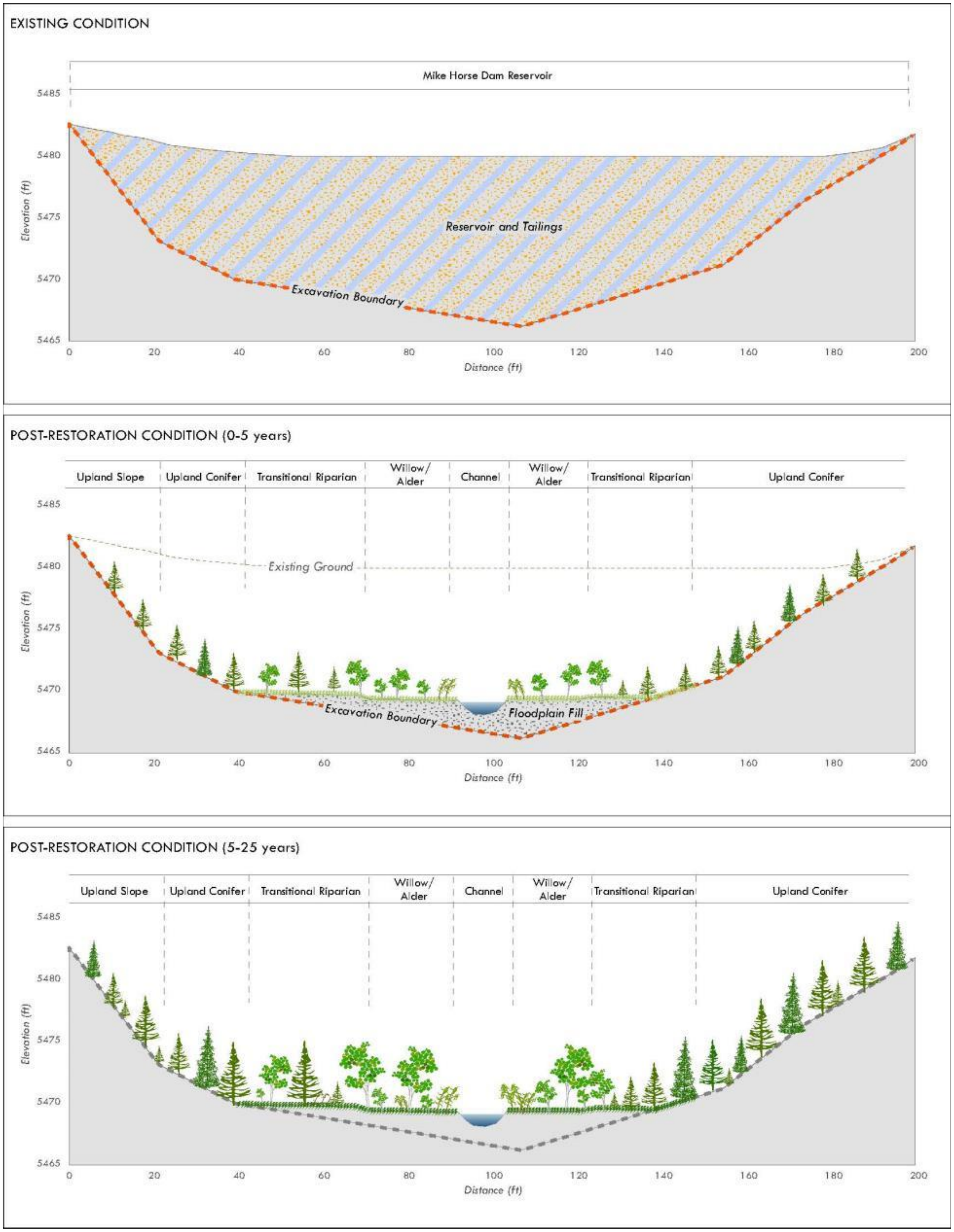


Figure 4-2. Reach 2 existing condition and estimated condition short- and long-term after restoration.

4.3 Reach 3 Lower Beartrap Creek

4.3.1 Introduction

Reach 3 extends from the Upper Beartrap Creek confluence with Mike Horse Creek to the confluence with Anaconda Creek. Preliminary grading, typical stream alignment, structure details, and planting/seeding plans are shown in Appendix A. Section 3 describes how design criteria are applied to Reach 3.

4.3.2 Restoration Strategies

The preliminary restoration plan for Reach 3 specifies construction of a moderately steep and entrenched, cobble dominated, riffle-pool B3 stream type developed within a relatively confined, terraced valley. Legacy mining impacts in Reach 3 are related to the excavation of the old Mike Horse townsite. Excavated material was sidecast and disposed of in the Reach 3 valley resulting in a much narrower and confined valley morphology than was likely present prior to mining activities in the UBMC project area. Because this material is not contaminated, it has been identified as a potential source of clean fill for restoration of the channel and floodplain. The proposed remedial and restoration grading surfaces propose to widen the valley adjacent to the townsite in order to generate clean backfill material and reduce the effects of the valley constriction on channel and floodplain hydraulics. The proposed restoration grading surfaces specify a valley width ranging from 85 feet at the confluence with Mike Horse Creek and Upper Beartrap Creek to over 225 feet near the confluence with Anaconda Creek.

Riffle depths in Reach 3 will average 1.0 foot with maximum pool depths of 3.1 feet (Appendix A, Sheet 13.1). The average channel gradient in Reach 3 will be 2.7%. Modeled shear stress values are high in Reach 3 with estimated mobile particle sizes in the active channel ranging from 377 mm (15-inch) to 450 mm (18-inch) for the Q25 and Q50 recurrence interval floods, respectively. Similar to Reach 2, channel bed construction will consist of constructed riffles with intermediate step pool structures designed to dissipate stream energy, provide vertical grade control, maintain floodplain connectivity, and increase aquatic habitat complexity. Channel bed features will be constructed with graded alluvium, coarse cobble, wood, and small boulders. A typical structure sequence for Reach 3 is provided in Appendix A on Sheet 7.2. Streambank treatments will be comprised of large wood structures on outside meander bends associated with pool channel units, vegetated wood and brush fascines on riffle, run and glide channel units, and vegetated soil lifts on up-valley riffle streambanks. Floodplain swales, roughness, and microtopographic grading will be used to create topographic heterogeneity on the floodplain and create elevations that intercept groundwater and support riparian vegetation establishment. Swales will also increase floodplain roughness, dissipate flood energy, and provide areas for sediment and nutrient storage. Typical streambank, channel, and floodplain treatment details are included in Appendix A (Sheets 14.0-14.8).

Along the east side of Lower Beartrap Creek in Reach 3, two adits are present (Flossie Louise Mine and Red Wing Mine). Because these adits are producing acid mine drainage, it will be necessary to separate this water from the main Lower Beartrap Creek channel to the greatest extent feasible. To accomplish this, a series of off-channel (stepped) wetlands and side channels will be constructed along the east side of the floodplain in Reach 3. Groundwater from the adits will be routed through the wetlands and eventually dispersed at the Anaconda Creek confluence.

The restoration plan proposes to relocate the confluence of Anaconda Creek and Lower Beartrap Creek approximately 250 feet up-valley and away from the water treatment plant infrastructure. The preliminary design is included on Sheet 10.0 in Appendix A. As shown, approximately 258 feet of channel would be constructed to connect Lower Beartrap Creek with Anaconda Creek. The channel slope will average 1.9% and the stream will be characteristic of a moderately entrenched, B3c stream type with riffle and pool bedforms. The existing secondary channel of Anaconda Creek would be maintained in its current location and will continue to provide important functions including distributing flow and sediment across the Lower Beartrap Creek floodplain. Minor streambank restoration will be required to reduce avulsion risk at the bifurcation point where the two channels diverge on Anaconda Creek.

The revegetation design for Reach 3 includes six revegetation zones which would support the following cover types: Willow/Alder, Cottonwood/Aspen, Natural Recruitment, Riparian Transitional, Emergent Wetland, Upland Conifer, and Upland Slope. These vegetation cover types are described in more detail in Section 3.7. The Willow/Alder and Cottonwood/Aspen cover types would occupy low elevation areas within the floodplain adjacent to the channel. At the downstream end of Reach 3, the Natural Recruitment cover type would be left as exposed alluvial material (sand, gravel and cobble) where willows, cottonwoods, and other native plants would be able to naturally colonize point bars. The Riparian Transitional cover type would link the near-channel zone with adjacent conifer forest. The Upland Conifer cover type would occupy higher elevation areas with a slope of less than 2.5:1 within the slope transition between the floodplain and existing upland vegetation. The Upland Conifer cover type in Reach 3 would typically be a narrow zone between the floodplain and existing upland vegetation, or the Upland Slope cover type which would occupy higher gradient slopes. The Upland Slope cover type would occur where the slope is steeper than 2.5:1; for example, if the slope adjacent to an old town site is excavated, large areas of east-facing slope will need to be revegetated.

Figure 4-3 provides a typical view of existing ground with approximate extents of contamination, estimated conditions immediately after restoration has been completed, and a desired future condition for the site once it has had time to mature.

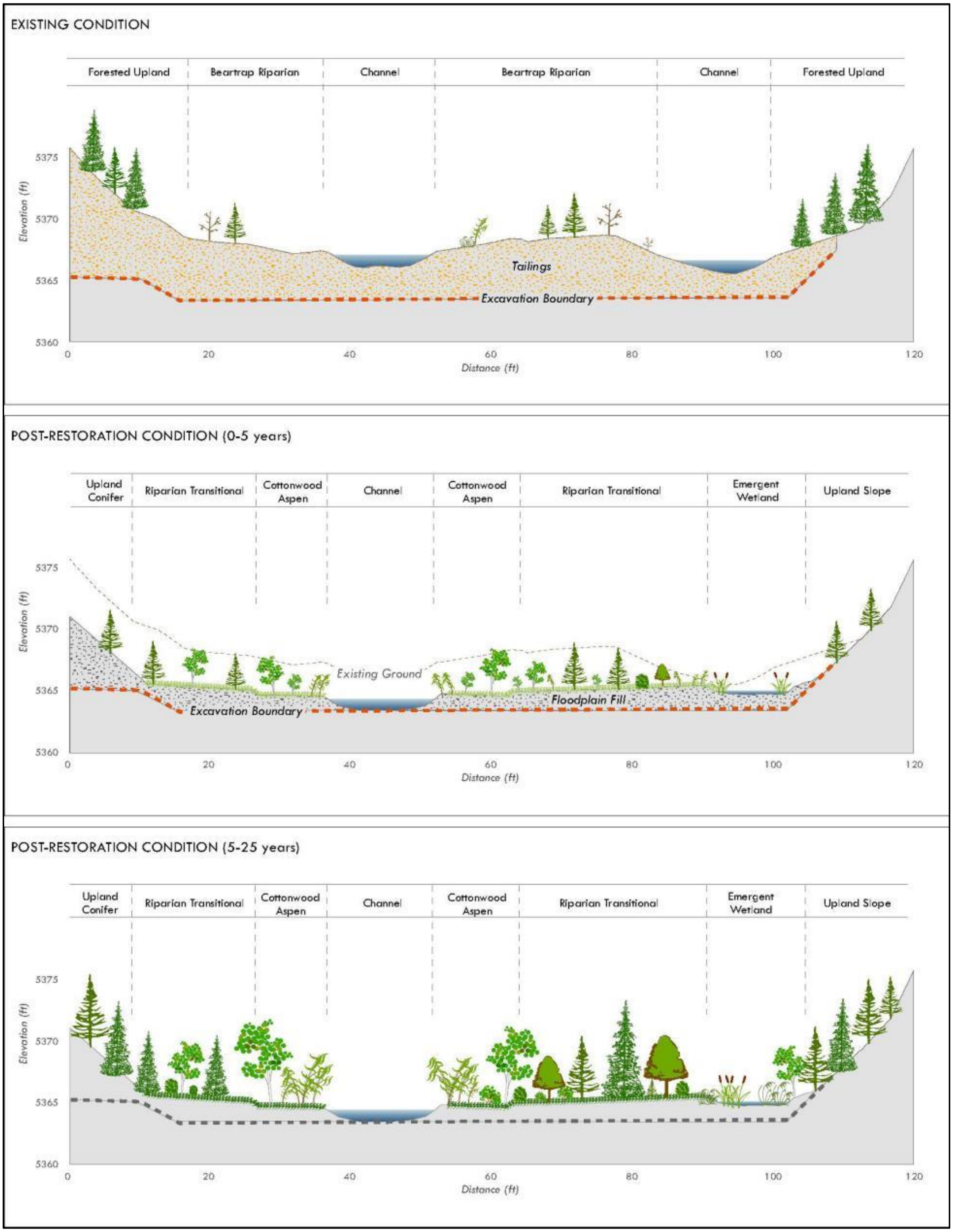


Figure 4-3. Reach 3 existing condition and estimated condition short- and long-term after restoration.

4.4 Reach 4 Upper Blackfoot River

4.4.1 Introduction

Reach 4 extends from the Lower Beartrap Creek confluence with Anaconda Creek to the Upper Blackfoot River confluence with Shaue (Shave) Gulch. This reach includes the floodplain adjacent to the currently operating water treatment plant. Preliminary grading, typical stream alignment, structure details, and planting/seeding plans are shown in Appendix A. Section 3 describes how design criteria are applied to Reach 4.

4.4.2 Restoration Strategies

Reach 4 includes 6,100 feet of the Upper Blackfoot River. Channel morphology in Reach 4 will transition from a moderately entrenched, cobble dominated, riffle-pool B3 stream type to a slightly entrenched, meandering, riffle-pool C3b stream type with a developed floodplain. As shown on Sheet 8.0 in Appendix A, the transition point will occur downstream of the water treatment plant where due to limited infrastructure and constraints, a wider floodplain and channel migration zone can be established, more closely emulating the likely historical morphology of the valley.

Bankfull channel widths will range from 25.9 feet for riffle and 31.1 feet for glide channel units. Riffle depths will average 1.2 feet and maximum pool depths will range from 3.1 feet to 3.6 feet. Channel slopes in Reach 4 will range from 1.9% near the confluence with Anaconda Creek to 1.4% near the juncture with Shaue (Shave) Gulch. Average mobile particle sizes in the active channel for the Q25 and Q50 recurrence interval floods range from 236 mm (9-inch) to 337 mm (11-inch), respectively. Because of the decreasing energy regime in Reach 4, the morphology of the channel will be characterized by alternating riffle and pool sequences compared to upstream reaches that are more confined and dominated by step-pool and interspersed riffle bedforms. Channel bed features in Reach 4 will consist of constructed riffle, run, pool and glide channel units constructed with graded alluvium, gravel, and cobble. Step-pool features are not a requirement in Reach 4 for stability or aquatic habitat purposes.

A typical structure sequence is provided in Appendix A on Sheet 8.2. As indicated, the channel planform will consist of alternative pool and riffle sequences. Streambank structures will consist of large wood structures positioned on outside meander bends to dissipate stream energy and provide aquatic habitat complexity, and a suite of deformable treatments including vegetated soil lifts and vegetated wood and brush fascines. Zones of moderate to high shear stress will be treated with Type 1 vegetated wood and brush fascines while more passive margins and streambanks will be treated with vegetated soil lifts and Type 2 vegetated wood and brush fascines. Typical streambank and channel construction details are included in Appendix A on Sheets 14.0-14.8. Streambank design criteria and treatments are described in Section 3.6 of this report.

The Reach 4 valley morphology and proposed floodplain grading plan is characterized by a broad channel migration zone ranging in width from a minimum of 85 feet adjacent to the water treatment plant to over 400 feet upstream of Shaue (Shave) Gulch confluence. Similar to the lower end of Reach 3, the valley will consist of a bankfull floodplain and a low terrace feature to accommodate flows greater than the estimated ±Q25 recurrence interval discharge. Because the valley is wider and flatter in Reach 4, additional floodplain treatments will utilized including alcoves, side channel wetlands, floodplain swales and microtopography, and side channels. Floodplain design criteria and treatments are described in Section 3.5 of this report.

The preliminary design for the confluence of Shaue (Shave) Gulch and the Upper Blackfoot River is included on Sheet 11.0 in Appendix A. As shown, approximately 360 feet of channel will be constructed to connect Shaue (Shave) Gulch will the Upper Blackfoot River. The channel slope will average 1.9% and the stream will be characteristic of a moderately entrenched, B3c stream type with riffle and pool bedforms. The channel and floodplain tie-in point is located approximately 75-feet downstream of the Mike Horse Road crossing of Shaue (Shave) Gulch and corresponds to a well-vegetated floodplain and stable riffle feature. If no longer required for access or transportation purposes, the existing culvert will be removed and the channel and streambanks restored through the footprint of the existing crossing. Channel and streambank treatments will be similar to those proposed for Reach 4 and consist of constructed riffles and a variety of streambank treatments including vegetated wood and brush fascines, vegetated soil lifts, and large wood structures.

The revegetation design for Reach 4 includes seven revegetation zones which would support the following cover types: Natural Recruitment, Riparian Shrub, Cottonwood/Aspen, Emergent Wetland, Riparian Conifer, Upland Conifer, and Upland Slope. Vegetation cover types are described in more detail in Section 3.8. Throughout Reach 4, the Natural Recruitment cover type would occupy point bars where willows, cottonwoods, and other native plants can naturally colonize the floodplain where substrate is alluvium. The Riparian Shrub cover type would occupy low elevation areas within the bankfull floodplain adjacent to the channel. The Cottonwood/Aspen cover type would occupy a low terrace zone within the floodplain, and would function as a transition zone between shrubs and conifers. Lower elevation features (up to two feet below bankfull) would be excavated within the floodplain to support the Emergent Wetland cover type, which would support a range of wetter, herbaceous species and remain inundated throughout much of the growing season. Other depression features would provide topographic diversity in the floodplain. The Riparian Conifer cover type would replace the Cottonwood/Aspen cover type in low terrace areas that are further from the main channel or in areas where the hydrology supports drier coniferous species. Upland Conifer and Upland Slope cover types may not be necessary in Reach 4 since mature upland conifers are already present to the toe of adjacent slopes. However, these cover types would be included if upland areas are disturbed during construction. Figure 4-4 provides a typical view of existing ground with approximate extents of contamination, estimated conditions immediately after restoration has been completed, and a desired future condition for the site once it has had time to mature.

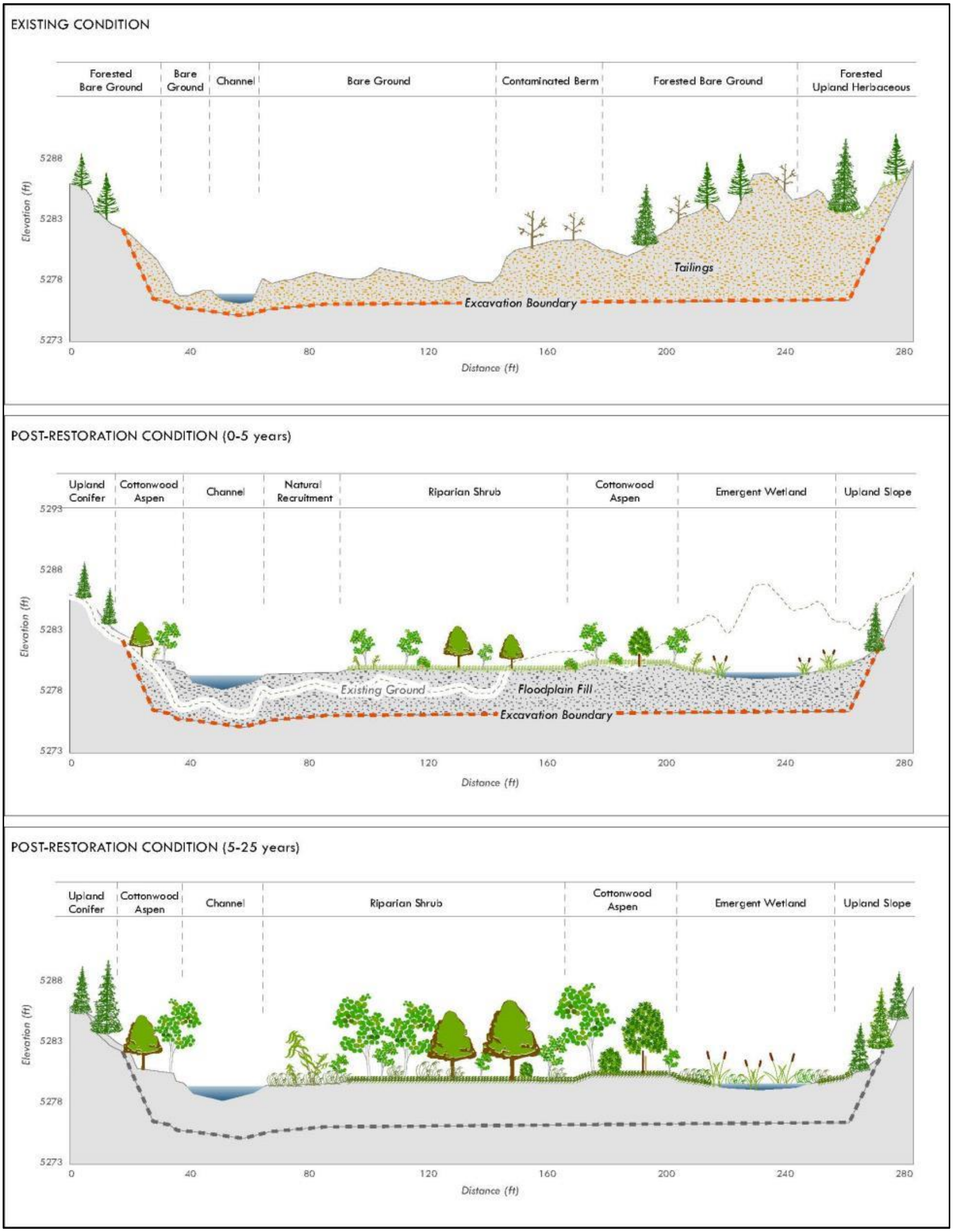


Figure 4-4. Reach 4 existing condition and estimated condition short- and long-term after restoration.

4.5 Reach 5 Middle Blackfoot River

4.5.1 Introduction

Reach 5 extends from the Blackfoot River confluence with Shaue (Shave) Gulch to a transition area in the Reach 6 upper marsh where the floodplain becomes a permanently saturated wetland. Preliminary grading, typical stream alignment, structure details, and planting/seeding plans are shown in Appendix A. Section 3 describes how design criteria are applied to Reach 5.

4.5.2 Restoration Strategies

Reach 5 includes 3,840 feet of the Middle Blackfoot River and transitions from an average slope of approximately 0.7% in the upper portion of the reach to less than 0.5% approaching the Reach 6 upper marsh. The preliminary restoration plan is to restore the river to a meandering stream type developed within a complex floodplain ecosystem with connected and disconnected side channels and wetlands.

In the upper reach, the channel type will be a slightly entrenched, riffle-pool C channel type characterized by cobble and gravel substrate, respectively. Channel sinuosity will average 1.7. Bankfull channel widths will range from 33.9 feet for riffle and 40.7 feet for pool and glide channel units. Riffle depths will average 1.4 feet and maximum pool depths will range from 2.7 feet to 4.9 feet. Average mobile particle sizes in the active channel for the Q25 and Q50 recurrence interval floods range from 144 mm (6-inch) to 202 mm (8-inch), respectively, compared to an average mobile particle sizes of 9-inches and 11-inches in Reach 4. The decreasing stream energy from Reach 4 to Reach 5 indicates that the long-term potential morphology will likely include a dynamic channel regime that oscillates between multi-channel and single-channel planforms depending on the frequency and magnitude of channel-changing disturbances such as large flood events. As observed on other alluvial systems in the Upper Blackfoot River watershed, lower gradient alluvial channels can respond to large flood events by braiding, which is typically proceeded by a period of vegetation and geomorphic recovery characterized by primarily single-thread channel planforms. In order to provide short-term stability to the floodplain to allow for riparian vegetation establishment, the design proposes a dominant bankfull channel with secondary floodplain channels that will be accessed during bankfull and greater events. Side channel entrances on the main channel will be designed to reduce avulsion risk.

A typical structure sequence for the C channel type in the upper portion of Reach 5 is included in Appendix A on Sheet 9.2. Channel bed features will consist of constructed riffle, run, pool and glide channel units constructed with graded alluvium, gravel and cobble. Streambank structures will include Type 1 vegetated wood and brush fascines on moderate to high stress streambank margins. Passive, low stress streambank margins including run and glide channel unit transitions on the inside point bars will be treated with Type 2 vegetated wood and brush fascine structures to provide floodplain roughness and support riparian plant establishment. Large wood structures will be used on outside meander ends to dissipate stream energy and provide aquatic habitat complexity. Alcoves, side channel wetlands, and floodplain swales will be integrated in the floodplain. Floodplain design criteria and treatments applicable to Reach 5 are described in Section 3.5 of this report.

As the valley slope flattens in the lower end of Reach 5, the channel morphology will transition to a low width to depth ratio, low gradient, gravel dominated E stream type with an average slope of less than 0.5%. Bankfull channel widths for riffle, run and pool channel units will range from 17.0 feet to 18.0 feet. Mean channel depths will range from 2.1 feet to 2.3 feet, with maximum pool depths of 6.3 feet. Average mobile particle sizes in the active channel for the Q25 and Q50 recurrence interval floods range from 100 mm (4-inch) to 156 mm (6-inch), respectively. As the energy gradient in Reach 5 continues to decrease approaching the upper marsh, more passive streambank treatments are appropriate including Type 1 vegetated brush fascines along the higher stress, outside meander bends, and Type 2 vegetated brush fascines along the more passive margins including riffle, run, and glide channel units. A typical structure sequence for the E stream type in Reach 5 is provided in Appendix A on Sheet 9.2.

The revegetation design for Reach 5 includes six revegetation zones which would support the following cover types: Natural Recruitment, Shrub Wetland, Emergent Wetland, Forested Wetland, Riparian Conifer, and Upland Conifer. Vegetation cover types are described in more detail in Section 3.8. The Natural Recruitment cover type would be left as exposed alluvial material (sand, gravel and cobble) on floodplain surfaces on point bars in the upstream portion of Reach 5 where the gradient is higher. The bankfull floodplain would occupy most of the restored surface in Reach 5 and would support the Shrub Wetland cover type. Lower elevation areas excavated within the bankfull floodplain would support the Emergent Wetland cover type. These areas would be connected to the main channel through ephemeral/ intermittent side channels.

In downstream portions of Reach 5, the Shrub Wetland cover type would transition into Forested Wetlands to tie in with existing mature vegetation communities at the lateral extents of grading. The Riparian Conifer cover type would occupy areas where the bankfull floodplain ties in with existing stands of conifers. The Upland Slope cover type would be included in areas where floodplain grading ties in with higher elevation upland vegetation communities at the outer extents of grading. Figure 4-5 provides a typical view of existing ground with approximate extents of contamination, estimated conditions immediately after restoration has been completed, and a desired future condition for the site once it has had time to mature.

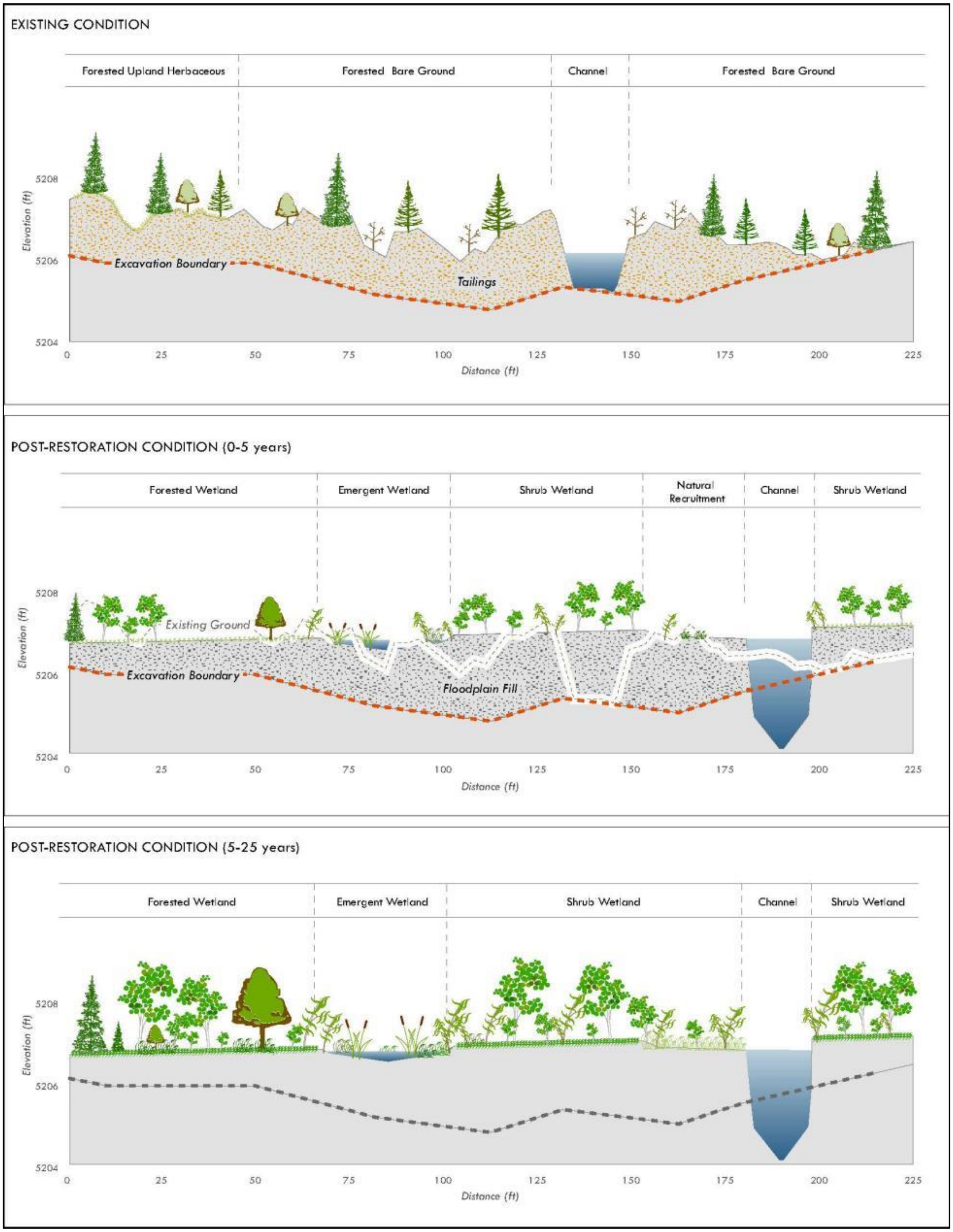


Figure 4-5. Reach 5 existing condition and estimated condition short- and long-term after restoration.

4.6 Reach 6 Lower Blackfoot River

4.6.1 Introduction

Reach 6, Lower Blackfoot River, includes a large wetland complex that consists of Emergent Marsh, Fen, Scrub Shrub, and Forested Wetland vegetation communities. This large wetland complex is a result of its unique landscape position where Pass Creek and Paymaster Creek both flow into the Blackfoot River from opposite sides of the valley. Alluvial fans from these tributaries, combined with tailings deposition, have created slightly convex landforms on the valley floor. In addition, the valley gradient is extremely flat, and groundwater is at or near the surface. Combined, these factors result in a low-gradient, multi-channel system where saturated conditions support perennial wetlands, and habitat is highly suitable for beavers. Abundant beaver dams further impound and store water on the surface, causing a mosaic of open water and the wetland types noted above. Hydrology within this wetland complex is supported by precipitation, groundwater seepage from adjacent hill slopes, surface water and groundwater from Pass Creek and Paymaster Creek, and surface water and groundwater from the Blackfoot River. At the lower end of Reach 5 and the top of Reach 6, fluvial disturbances are more frequent, and the wetland consists of an emergent marsh with mineral soils and a thin surface layer of accumulated organic material. Further from the channel and outside the zone of fluvial disturbance, peat soils have developed where positive groundwater pressure has likely been present without significant interruption for hundreds, or possibly thousands, of years. Paludification (see description below) of bordering forested areas suggests that the water table has been on a rising trend throughout this reach for many years.

The wetland complex has important ecological integrity and is a highly functioning system that has mostly recovered from past human disturbances. While this recovery indicates high resilience in the marsh portion of the wetland complex, much of the recovery has occurred relatively recently as a result of beavers recolonizing the area and raising the water table. These wetlands provide several functions including maintenance of water quality, ground water discharge sites, surface and ground water flow regulation, water storage, and wildlife habitat. In addition, several rare and sensitive wetland types were identified within the wetland complex including forested and fen wetlands (Appendix D). Forested wetlands are a rare wetland type in Montana and are difficult to restore due to the length of time it takes to re-establish the forest canopy. Paludified forests, areas where upland forests are converting to wetland forests due to peat accumulation, are difficult to replicate because they are typically colonized by fen-adapted plant species over time, including *Sphagnum* spp., due to rising water levels. Fens are biologically significant due to their unique plants and slow rate of peat accumulation (approximately 8 inches/1,000 years). The slow rate of peat accumulation within fens indicates that they are stable landscape features that have developed over many thousands of years but also makes them exceptionally vulnerable to disturbances. The fen peat combined with permanently saturated conditions makes this type of wetland superior at attenuating metals and at low risk for metal mobility. The U.S. Army Corps of Engineers Helena

Regulatory Office regulates fens as a special aquatic site in Montana because of the critical functions they provide as well as their low resilience to disturbances.

As with upstream reaches, restoration will be integrated and coordinated with remedial activities in Reach 6. Restoration will emphasize preserving rare wetlands where possible, and restoring wetland functions in areas where contaminated substrate is removed. Therefore, the combined restoration/remediation action will need to balance removing contaminants with preserving rare and highly functioning wetland types. Both removal and preservation have potential risks and benefits that will need to be evaluated further during the design process.

To support decision-making at the preliminary stage, several analyses have been completed. Extents and depths of contamination are reported in Spectrum Engineering and Pioneer Technical Services (2013) and Tetratech (2013). Applied Geomorphology evaluated risks of avulsion and sediment dewatering within the Marsh area, particularly related to the convex floodplain feature associated with Pass Creek's alluvial fan (Applied Geomorphology 2013). Vegetation and wetland mapping for this area are described in Section 2 and Appendix D. Based on these analyses, several factors need to be considered during design when selecting a balance between removing contaminated sediments and preserving existing wetlands. These include: (1) contaminated sediments are present throughout the marsh area, and are mostly concentrated in the zone of fluvial disturbance described above, although some contamination may be present in wetlands called out for preservation; (2) several potential avulsion paths are present in contaminated portions of the marsh area; (3) due to the ephemeral nature of beaver dams, areas that are now ponded and saturated could potentially dry out, allowing metals to oxidize; and (4) marsh wetlands are more resilient than fens and forested wetlands, so removal activities should be avoided where possible in fens.

A range of alternatives has been identified in a draft feasibility study with respect to addressing contaminated sediments in Reach 6 (Pioneer Technical Services 2013). Alternatives include no action, monitored natural attenuation, removal and land disposal, and isolated removal and land disposal. A no action alternative would rely on natural attenuation of contaminants by wetlands in Reach 6. Monitored natural attenuation would include steps to evaluate effectiveness of natural metals attenuation in a way that could inform adaptive management actions; this would leave open the possibility of implementing remedial actions if necessary. Removal and land disposal is split into three sub-alternatives by area: upper reach above Pass Creek, Pass Creek confluence, and a lower reach below Pass Creek. Within these areas, contaminated sediments would be removed based on further analysis and feasibility of dewatering, access and other feasibility factors. Another alternative in the draft feasibility report is linked to removing contamination based on existing vegetation communities identified in this plan where those communities correspond with visible surface tailings. For example, Filled Scrub Shrub and Forested Bare Ground (Appendix D) have visible surface tailings.

In addition to these alternatives, another potential scenario was identified based on the analysis of avulsion risk (Applied Geomorphology 2013). According to this analysis, potential consequences of an avulsion include sediment recruitment and tailings de-saturation. As part of the potential remediation scenario, the Blackfoot River would be realigned to follow the most likely avulsion path, and this would contribute to dewatering the Pass Creek confluence area, which would allow removal of contaminated sediments in this area.

From a restoration perspective, all of these alternatives and scenarios could be compatible with the goals and objectives outlined in Section 1 of this plan, assuming cleanup actions are balanced with the end goal of leaving behind a functioning, self-sustaining ecosystem. As part of future design phases addressing Reach 6, it will be necessary to apply a logical framework to establish a priority ranking of potential remedial actions and associated restoration. This framework should balance risks considered by remedy with risks to the unique wetland ecosystem in Reach 6. An example order of priority for removing contaminated sediments might be: (1) remove contaminated sediments that are currently unsaturated. Because these areas are above the water table, metals are not being attenuated, so soils tend to be exposed and do not support natural densities of vegetation. Metals from these soils continue to wash into the aquatic system, affecting water quality; (2) remove contaminated sediments from areas where risk of mobilization or de-saturation due to avulsion is highest; (3) remove contaminated sediments above a series of historical cross-valley “drill roads” that functioned to impound some sediments; and (4) remove additional contaminated sediments down valley depending on available resources and feasibility. From a restoration perspective, the greater the removal areas, the more important it would be to carefully evaluate effects of removals and related excavation on wetland hydrology and function, and on potential of the site to be restored as a self-sustaining wetland system.

4.6.2 Restoration Strategies

Two revegetation cover types are included in Reach 6: Shrub Wetland and Wetland Complex. Shrub Wetland would be located adjacent to the channel as it transitions from Reach 5 into Reach 6. The Wetland Complex cover type consists of plant species found in emergent, shrub, and forested wetland communities. Although this cover type covers a broad area, patches of emergent, shrub, and forested wetlands will be placed in distinct areas based on topography, landscape position, and soil saturation. This would result in a mosaic of wetland types in Reach 6, and the distribution of different wetland types would be somewhat driven by removal patterns.

Where it is necessary to achieve suitable elevations for wetland development, restored areas would be backfilled with vegetative cover soil with approximately 5% organic content or greater. Several factors would need to be considered to protect existing wetlands during remediation or restoration activities. Dewatering or increasing soil surface bulk density via compaction can lower the water table, allowing organic layers over mineral soils and peat to oxidize. Oxidized organic material can result in the soil surface subsiding due to increased decomposition. Even short periods of drying will allow oxygen to enter the soil and greatly increase decomposition rates. Subsidence of the soil surface occurs as the water table is lowered and upper organic layers collapse causing bulk density to increase and organic matter to physically breakdown through accelerated mineralization. Reclaimed areas would be seeded and planted with containerized trees, shrubs, wetland plugs, and salvaged wetland donor soils as they are available.

5 Integration with Remedial Actions

In October 2013, DEQ issued a second draft of the UBMC Conceptual Removal Plan (Spectrum Engineering 2013) describing the general schedule and sequencing of remedial and restoration actions. The removal philosophy is to start at the top of the Mike Horse Creek and Beartrap Creek drainages and methodically remove contaminated material from upstream to downstream in order to minimize the potential of downstream re-contamination (Spectrum Engineering 2013). As described in the report, the major risk of recontamination would be if the Beartrap Creek tailings impoundment failed similar to the 1975 event, or due to failure related to piping. These potential risks will be minimized by maintaining and upgrading the capacity of the existing diversion ditch in the impoundment and by installing a sediment dam with a drop inlet culvert across Mike Horse Creek immediately upstream from the Beartrap Creek diversion.

The UBMC Conceptual Removal Plan anticipates sediment removals beginning in 2014 and continuing through 2018. In total, approximately 810,000 cubic yards (uncompacted) of material will be removed from the project area, excluding upland removals. To restore the floodplain, it is estimated that approximately 92,100 cubic yards of clean backfill will be required. As described in the UBMC Conceptual Removal Plan, two sources of clean backfill have been identified, including the former Mike Horse townsite area and the Section 35 repository.

5.1 Removal Sequencing and Integration Tasks

The following section describes the draft remediation schedule and the restoration actions that will be integrated in each phase of the removal process. The schedule depends on multiple variables that influence production rates including weather, site conditions and uncertainties related to removal extents. Several components of the project implementation schedule will need to be coordinated closely between remediation and restoration. These components include but are not necessarily limited to: (1) developing design packages, bid documents, and technical specifications; (2) coordinating temporary diversions to manage surface water and work area isolation; (3) developing sediment control measures and Best Management Practices (BMPs) to minimize impacts to water quality during and following construction; (4) identifying access road locations and phasing of construction and decommissioning; (5) identifying salvageable on-site materials (i.e. trees and alluvium) and stockpile locations; and (6) coordinating changes to the water treatment plant to ensure the restoration design is compatible and minimizes risk to site infrastructure.

The following task lists are provisional and will be modified and updated as new information becomes available.

5.1.1 2014 Tasks

Removal of mine waste material in the Mike Horse and Beartrap Creek valleys is scheduled to begin in 2014. In Reach 1, approximately 1,200 feet of the Mike Horse Creek valley beginning at the coffer dam will be excavated to bedrock to allow the bedrock to be sealed and/or a surface water collection system to be installed to prevent the creek from draining into the mine workings (Spectrum Engineering 2013). In Reach 2, approximately 110,000 cubic yards of tailings will be removed from the impoundment. Tasks in 2014 that will require integration between restoration and remediation are summarized in Table 5-1.

Table 5-1. 2014 list of anticipated tasks requiring integration between remediation and restoration.

Item	**Description**
Design and bid documents	• Prepare design and bid documents for removal and restoration activities in Reach 1 MHC[1] and Reach 2 UBTC[2]
Removals	• Remove waste rock from upper MHC[1] in Reach 1 • Remove approximately 110,000 cubic yards from Reach 2 UBTC[2] impoundment (Phase 1)
Restoration	• Revegetate disturbed slopes on Little Nell and Reach 1 MHC waste dumps from coffer dam downstream approximately 1,200 feet depending on timing and production rate • Reconstruct Reach 1 MHC floodplain and waste dump footprints downstream approximately 1,200 feet depending on timing and production rate • Characterize townsite borrow material and other sources of borrow to be used for floodplain backfill (all phases)
Temporary diversions	• Divert MHC in pipe from above coffer dam down to USFS road
Sediment control	• Construct haul road embankment / sediment pond across Reach 1 MHC
Access roads	• Design and construct haul road through townsite to Reach 2 UBTC impoundment • Upgrade existing road to Kornecs and replace existing culvert
Material stockpiles	• Identify material stockpile locations (clean backfill) for restoration activities in Reach 1 MHC and Reach 2 UBTC

[1] MHC=Mike Horse Creek; [2] UBTC=Upper Beartrap Creek;

5.1.2 2015 Tasks

The UBMC Conceptual Removal Plan anticipates the removal of an additional one-third of the tailings impoundment in 2015 (approximately 240,000 cubic yards). Restoration of the Reach 2 Upper Beartrap Creek channel and floodplain will proceed although the exact scope will depend on the progress of tailings removal in 2014 and 2015. A temporary bypass channel will be constructed to the east side of the valley. As indicated in the UBMC Conceptual Removal Plan, it will be imperative to expedite embankment removal and restoration efforts in 2015 to avoid risk of a major storm event exceeding the hydraulic capacity of the Upper Beartrap Creek diversion and inundating the excavation area. Impoundment dewatering will continue through 2015 until restoration actions are completed in Reach 2. Major tasks in 2015 that will require integration between restoration and remediation are summarized in Table 5-2.

Table 5-2. 2015 list of anticipated tasks requiring integration between remediation and restoration.

Item	Description
Removals	• Complete any removals not completed in 2014 in Reach 1 MHC • Remove approximately 240,000 cubic yards of mine waste in Reach 2 UBTC impoundment (Phase 2 and 3A)
Restoration	• Reconstruct a portion of Reach 2 UBTC • Revegetate east side impoundment hillside • Monitor MHC reclaimed waste dump footprints and implement additional revegetation techniques as necessary
Temporary diversions	• Construct temporary diversion for Reach 2 UBTC channel along east side of valley through impoundment and downstream to confluence with MHC
Sediment control	• Monitor erosion control measures and BMPs in Reach 1 MHC and Reach 2 UBTC and install additional erosion control/stabilization techniques as necessary
Material stockpiles	• Determine materials (trees, other) stockpile locations for 2016 work activities • Determine stockpile locations for floodplain backfill material to be used in 2016, as applicable

[3] LBTC=Lower Beartrap Creek; [2] UBFR=Upper Blackfoot River;

5.1.3 2016 Tasks

In 2016, the remainder of the tailings impoundment will be removed including the diversion system (approximately 50,000 cubic yards). Restoration of the channel and floodplain in Reach 1 MHC and Reach 2 UBTC will be completed. Reclamation will proceed with tailings removal from the top of Reach 3 Upper Beartrap Creek downstream to the Mary P. waste dump or water treatment plant. A temporary bypass channel and haul road will be constructed. The townsite borrow will be developed. In 2016, it will be necessary to continue monitoring revegetation and slope stabilization measures in Reach 1 Mike Horse Creek and the east hillslope in Reach 2 Upper Beartrap Creek. If erosion control and other BMP measures are not functioning as designed, additional corrective measures will be taken through an adaptive management approach. Major tasks in 2016 that will require integration between restoration and remediation are summarized in Table 5-3.

Table 5-3. 2016 list of anticipated tasks requiring integration between remediation and restoration.

Item	Description
Design and bid documents	• Prepare design and bid document for remainder of removal and restoration activities in Reach 1 MHC, Reach 3 LBTC, Anaconda Creek, Reach 4 UBFR, Shave Gulch, Reach 5 MBFR, and Reach 6 LBFR
Removals	• Remove approximately 50,000 cubic yards of mine tailings in Reach 2 UBTC (Phase 3B) • Complete mine tailings removal in Reach 1 MHC • Clear and grub Reach 3 LBTC and Reach 4 to Mary P. waste dump or water treatment plant • Remove and stockpile existing trees and salvageable plant material from townsite borrow area • Remove mine waste in Reach 3 LBTC and Reach 4 UBFR downstream to Mary P. waste dump or water treatment plant • Begin regrading of townsite borrow
Restoration	• Reclaim and revegetate west hillside in Reach 2 UBTC • Complete remaining channel and floodplain restoration actions in Reach 1 MHC and Reach 2 UBTC • Implement restoration actions in Reach 3 LBTC and Reach 4 UBFR downstream to Mary P. waste dump or water treatment plant • Replace existing culvert at water treatment plant with bridge
Temporary diversions	• Decommission and reclaim Reach 2 UBTC diversion channel • Construct temporary diversion for Reach 3 LBTC and Reach 4 UBFR downstream to Mary P. waste dump or water treatment plant • Collect surface water from Anaconda Creek secondary channel and divert into main Anaconda Creek channel
Sediment control	• Monitor erosion control measures and BMPs in Reach 1 and Reach 2 and implement additional controls as necessary • Develop and implement townsite BMPs and erosion control measures
Access roads	• Construct temporary haul road in Reach 3 UBTC downstream to Mary P. waste dump or water treatment plant
Material stockpiles	• Identify material stockpile locations to support restoration actions in Reach 4 UBFR, Reach 5 MBFR[1], and Reach 6 LBFR[2]
Water treatment plant	• To be determined

[1] Middle Blackfoot River; [2] Lower Blackfoot River

5.1.4 2017 Tasks

Remaining tasks in 2017 include remediation and restoration work in Reach 4 Upper Blackfoot River, Reach 5 Middle Blackfoot River, and Reach 6 Lower Blackfoot River. At this time, remedial and restoration concepts in Reach 6 are still in the conceptual design phase. Both removal and preservation have potential risks and benefits that will need to be evaluated further during the design process. As with upstream reaches, restoration will be integrated and coordinated with remedial activities to ensure restoration and remedial actions balance removing contaminants with preserving rare and highly functioning wetlands in Reach 6.

Tasks in 2017 that will require integration between restoration and remediation are summarized in Table 5-4.

Table 5-4. 2017 list of anticipated tasks requiring integration between remediation and restoration.

Item	Description
Removals	• Remove mine tailings from Mary P. or water treatment plant in Reach 4 UBFR downstream through Reach 5 MBFR • Remove contamination from Reach 6 LBFR wetland complex and other upland sites
Restoration	• Restore Reach 4 UBFR from Mary P. or water treatment plant downstream through Reach 5 MBFR and Reach 6 LBFR • Reclaim and revegetate townsite borrow cut if not completed in 2016 • Import additional clean fill from Section 35 or townsite borrow as needed to restore the floodplain in Reach 4 UBFR, Reach 5 MBFR, and Reach 6 LBFR
Temporary diversions	• Construct temporary diversions from water treatment plant or Mary P. downstream through Reach 5 MBFR and Reach 6 LBFR
Sediment control	• Evaluate need for additional sediment control measures in Reach 1 MHC, Reach 2 UBTC, and Reach 3 LBTC • Implement BMP and erosion control measures as necessary to support removal and restoration activities in lower Reach 4 UBFR, Reach 5 MBFR and Reach 6 LBFR
Access roads	• Construct temporary haul road from Stevens Gulch downstream through Reach 5 MBFR and Reach 6 LBFR • Decommission road through townsite if not completed in 2016 • Decommission temporary haul roads in Reach 5 MBFR and Reach 6 LBFR, as necessary

5.1.5 2018 Tasks

The UBMC Conceptual Removal Plan anticipates substantial completion of both remedial and restoration activities by 2018. In 2018, any additional work not completed in previous years will be undertaken. Monitoring of restoration activities will occur in 2018 and include but not necessary be limited to channel, floodplain and revegetation monitoring, inspecting and cleaning sediment control structures and BMPs as necessary, measuring metal concentrations in sediments, and monitoring effectiveness of steep slope erosion control and revegetation measures in Reach 1, Reach 2, and Reach 3 of the project area. Maintenance activities will be identified and implemented through an adaptive management approach.

6 Conclusion

The Montana Department of Justice Natural Resource Damage Program (NRDP), in cooperation with the Montana Department of Environmental Quality Hazardous Waste Site Cleanup Bureau (DEQ), has prepared a preliminary restoration design for the Upper Blackfoot Mining Complex (UBMC) near Lincoln, Montana. Regulatory activities in the UBMC began in 1987 to reclaim the Mike Horse Mine under Montana's Abandoned Mine Reclamation Program. The implementation of the removal and restoration actions of the mine wastes within the UBMC is being led by DEQ under a watershed restoration agreement between the U.S. Forest Service and the State of Montana.

This preliminary design and supporting information contained in Appendices A-D define how channel, floodplain and riparian resources will be restored in a phased, multi-year adaptive management approach. The primary restoration goals are to create conditions that will result in clean, connected habitat for westslope cutthroat trout, support downstream populations of bull trout and other important aquatic species, improve water quality, and maintain adjacent riparian and terrestrial habitats.

To accomplish these goals, restoration work will be closely integrated with remedial actions, and involve reconstructing approximately 3.6 miles of channel beginning at the headwaters of the Blackfoot River in Mike Horse Creek and Upper Beartrap Creek, and proceeding downstream to the wetland complex located in Reach 6 of the project area. The existing channel and floodplain morphology will be modified to include riffle and pool stream types developed within narrow to broad, vegetated floodplain corridors. A variety of channel bed, streambank, and floodplain restoration treatments will be incorporated in the design to provide for short-term stability until vegetation establishes and provides long-term stability to the channel and floodplain resources.

Next steps in the planning process include: (1) continued integration with DEQ and its contractors to ensure remedial and restoration designs support a desired restoration outcome; (2) conducting additional field investigations to support final design; (3) preparing final designs, bid packages, and technical specifications in coordination with DEQ and its contractors; (4) managing construction; and (5) developing monitoring and evaluation protocols to guide adaptive management of the project over time. Work is anticipated to begin in 2014 and continue through 2017.

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